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GUAM WAVE RECORDER INSTALLATION: II

BY

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ABSTRACT

In order to study the relationships among microseisms, typhoons and the resulting waves, a series of three wave recorders were installed around Guam, M.I., to operate in conjunction with the microseismic station of the Naval Research Laboratory. The installation was made during the summer of 1952 and the equipment operated until Typhoon Hester on 31 December 1952. Presented in this report are the details of the equipment, the sea installation, the telemetering circuits and the recording stations. Also presented in an Appendix are the analyses of the wave records for the period of operation.

INTRODUCTION

In the study of the relationship between microseisms and hurricanes or typhoons, it became apparent that there was a question as to whether the microseisms were generated in the storm area and then propagated through the ocean bottom to the seismograph, or whether the generation of microseisms occurred relatively near the seismograph after energy had been propagated by surface water waves from the storm area(1)*.

It was decided by the U.S. Navy that a field study of this problem should be made on Guam, M.I., because: (1) the island was effectively a column in the middle of an extremely large expanse of the ocean; (2) it was in an area subject to many typhoons; (3) there was already a tripartite seismic station in operation; and (4) there was an active typhoon-tracking squadron in the area. It would, however, be necessary to install wave recorders at various points around the island.

A study of the charts of Guam indicated that it should be possible to provide complete coverage of the island (in regard to microseism studies) with a minimum of three wave measuring instruments, if they could be properly placed. An agreement was reached between the Office of Naval Research and the University of California whereby two engineers** made a survey of Guam during May 1951. As a result of this survey, it was decided that such a program would be feasible; and three locations were decided upon: Orote Point, Ylig Bay and Tarague Wells. These locations were chosen on a basis of coverage, feasibility of installing the pressure heads and submarine cable, the availability of power supply and telemetering circuits, and instrument housing facilities.

As a result of this initial survey, a contract was negotiated whereby the University of California was to: (1) construct, test and fabricate the necessary Mark IX pressure heads, together with the telemetering units;

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* Superscript numbers in brackets refer to References at end of report.

** R. L. Wiegel and F. E. Snodgrass

(2) provide engineers*** to supervise the installation and maintenance of the pressure heads, telemetering equipment and recording units; and (3) instruct Naval personnel of the Microseism Research Laboratory in the maintenance and operation of the shore equipment of the wave recorders.

GENERAL CONSIDERATIONS

Selection of Sites:

The primary requirement in selecting the sites for the recorders was that at least one instrument would be exposed directly to the waves, regardless of the wave direction, in deep water. Examination of Figure 1 indicates that this requirement was not fulfilled completely, since waves from the south cannot reach either the Ylig Bay or the Orote point recorder without some refraction and/or diffraction around the island. Unfortunately the lack of power and telephone lines on the southern end of the island made it impractical to install a fourth recorder to cover the small section not covered by the other recorders.

A need for close synchronization between the three wave recorders and several seismic recorders required that all recording be done at a central laboratory. The shore sites, therefore, had to be close to telephone and power lines so that telemetering of the wave data to the central laboratory could be accomplished. Battery or gasoline generator operated radio telemetering links were considered impractical.

The general locations of the instruments, therefore, were selected on the basis of exposure to the sea and availability of power and telephone lines. The locations of the underwater units, the routing of cables and the locations of shore instruments were selected after detailed surveys of the reefs and beaches, the jungle adjacent to the beaches and the existing roads.

Design of Tripods:

The information available at the time of the installation indicated that the sea bottom would be very rough, due to large coral heads, holes, and crevices. Actually very little detailed information was available for any of the three sites. A tripod, therefore, had to be built high enough that the pressure head (installed near the top of the tripod) would be in water relatively undisturbed by the bottom conditions; and the dimensions of the base had to be such that the tripod would be stable. The tripods were 20 feet high and had bases of fourteen feet (see Figure 28).

Routing of the Cables:

Two possibilities existed for routing the armored cables from the water's edge to the tripods. They could be layed in the bay out through the bay entrance and thence parallel to the reef edge, but seaward of it, to the tripods. Or else they could be layed on the reef, in crevices whenever possible, and anchored to the reef, as far as the reef's edge, thence in surge channels off the reef into deeper water, weighting the cables most exposed by securing heavy chains along their length.

*** F. E. Snodgrass and M.A. Hall.

Design of the Recording System:

In order to be able to correlate wave conditions with the microseismic records, it was desirable to record the waves at the same location at which the tripartite seismic recorders were located. This necessitated the development of a telephone telemetering system. However, past experience during typhoons which passed over Guam showed that in case of such an event, telephone lines might blow down. This necessitated the installation of standby recorders, located in typhoon-proof shelters, at the sites where the cables came ashore from the pressure heads. Moreover, as power lines would be down if the telephone lines were blown down, it was necessary to utilize battery powered standby units.

INSTALLATION OF THE PRESSURE HEADS

Mooring the Diving Tug:

Since several working days were required at each site, the need for a securely moored working platform was considered to be of primary importance. A YTB tug (Figure 23) was selected as the working platform because of its large, low after deck, comparatively small size, and its good maneuverability. Other vessels such as ARS Salvage Ships, Net Tenders, and ATF Fleet Tugs were considered too large to maneuver close to the reef. As the YTB was not considered a sea-going vessel, it was escorted at all times by a larger ship, usually of the ATF class. The escort ship also carried the explosives, the tripod and the sea moorings, installing the latter.

At all three sites the YTB tug, used as a working platform was held in position with a three point mooring system. At Orote Point, three moorings (each consisting of a 100 pound anchor, 150 feet of 3/4-inch chain, and a 500-gallon buoy), were installed. Lines attached to the moorings, two of which were secured near the stern of the tug and one at the bow, held the tug in the correct position over the tripod site. At Tarague Beach and Ylig Bay only one sea mooring was installed (3000-pound anchor, 500 feet of $1\frac{1}{2}$-inch chain, and a 600-gallon buoy) while the other two mooring lines were connected directly to the reef (Figure 31).

The sea moorings were laid by the escort vessel. Figure 24 illustrates schematically the desired position of the mooring relative to the tripod and the reef, and the method of positioning the ship so that the mooring would be dropped at the desired position. Figure 25 shows the mooring in the water with the tripod suspended from a second buoy. Figures 26 and 27 are photographs taken aboard the Coast Guard Cutter that laid the Ylig Bay mooring. The mooring chain was lashed to the deck with small manila lines. The two buoys and the tripod with the chains attached were hung over the side and lashed to the gunwale with small manila lines. The anchor also was hung over the side and secured with a pelican hook. When the ship crossed the desired position the pelican hook was tripped releasing the anchor. The manila lines lashing the chain to the deck broke as the chain ran over the side and when all the chain was gone the buoys and tripod lashings were broken by the weight of the chain. The moorings were thus dropped in place with the ship underway.

The mooring lines attached to the reef were pulled into position by the tug. A messenger line was shot ashore from the tug with a line-throwing gun and a four inch manila line then was pulled to the reef by hand with the

messenger line. The four inch manila lines were then used to pull the 7/8 inch diameter steel mooring lines off the reef (Figures 32 and 33). When approximately 200 feet of mooring line was taken aboard the tug, the mooring line was secured to a snubbing line on the reef so that the tug could take tension on the reef lines to pull itself into position.

Upon completion of the installation, the mooring lines were pulled back on the reef with tractors, but the sea moorings were left in place for future servicing of the pressure heads.

Installation of the Tripods:

A. Orote Point: The shoal area seaward of the end of the Apra Harbor breakwater was smooth hard coral with no sand. The bottom had a gradual slope toward the sea and toward the harbor entrance until the depth of water was about 10 fathoms. At this point the bottom slope increased abruptly, and appeared to the drivers to form an underwater cliff. Coral growths on the bottom were generally not more than one foot high and a site for the tripod was located without difficulty. A jagged hole about 18 inches deep was found at one point that served as a mounting hole for one leg of the tripod. Two other holes, about two feet square, were dug with air-driven chipping hammers to the same depth for the other tripod legs.

The location of the holes with respect to each other was determined by an angle iron template constructed to the dimensions of the tripod base. Standard chipping hammers were used, without difficulty, to dig the holes. The air pressure to the hammers had to be increased to compensate for the back pressure of the water, and the correct chipping tool had to be used. Narrow chisel tools were easily driven into the bottom, but they stuck and could be removed only with difficulty. Wide spade tools failed to cut the bottom.

Divers in full deep-sea dress (see Figure 39) had difficulty in bending over the hammer to observe their work and in applying pressure to the hammer. The divers' hands were also cut and bruised on the lead belt about their waists. Some divers found they could work best by holding the hammer with one hand at their side. By standing erect and leaning on the hammer with arm held stiff, they could look out the side port of the helmet to observe their work. Also, divers were worked in pairs to overcome the inconvenience of handling the hammer. In this case the hammer was held between the divers who stood in a semi-crouch position. Divers working in shallow water diving masks (Figure 36) proved to be more efficient than divers working in deep-sea dress because they could handle the hammer without difficulty. Divers in full deep-sea dress required approximately 10 hours of bottom time to dig holes two feet square and one and one-half feet deep. With shallow water diving masks, the divers dug the same size hole in about three hours.

The tripod was floated by means of several small buoys and was towed from the harbor to the site. After the buoys had been cut free, divers in shallow water masks guided the legs of the tripod into the holes as it was lowered. The diving tug lowered the tripod into position by a single line attached to the top of the tripod.

Several methods of cementing the tripod legs into the holes were considered. The technique to be described was selected in preference to cementing with cement guns, underwater cement buckets, or cement trammels,

primarily for the simplicity of the system. Also the need for obtaining the full strength of the concrete was not considered important. Portland cement was mixed with sand, coral gravel and fresh water, in standard ratios to give a moderately stiff mixture (Figure 44). The concrete then was poured into one cubic foot burlap sand-sacks and lowered to a diver (Figure 43, 45, 46) who placed them in the hole around the legs of the tripod and tamped them into position. After the holes had been filled, sharply pointed 18 inch lengths of reinforcing rods were lowered to the diver. He drove these rods into the sacks with an eight-pound sledge hammer in order to bind the sacks together. Seepage of cement through the coarse gunny-sacks also provided a bond between sacks.

B. Tarague Beach: The bottom of the Tarague Reef was all coral except for small sand pockets. Coral growths were usually about one foot high, with occasional growths two to four feet high. The bottom was relatively flat except for ditches that were two to six feet in depth and five to twenty feet wide. The ditches were extensions of the surge channels that scarred the reef face and were fifty to seventy-five feet apart in the area selected for the tripod. A level area was found, approximately midway between two ditches, on which to locate the tripod.

Instead of digging holes for the tripod legs with chipping hammers as was done at Orote Point site, the holes were blasted in the bottom with explosives. To mount the explosives on the bottom, a triangular angle iron template was built that held three ten-pound shape-charges at each corner. The nine charges were connected to primer cords which in turn joined to a single primer about ten feet below the surface. A float at the surface supported the end of the primer cord where it connected to an electrical detonator cap. Approximately 150 feet of electrical cable was attached to the cap in order to allow the ship to move out of range of the explosion.

The shape-charges used in these operations were standard military explosives designed to focus the explosive forces over a small area. Focusing of the explosion is accomplished by means of the geometrical shape of the charge. Maximum focusing occurs a specific distance below the base of the charge, requiring that the explosive be mounted on a small stand-off tripod.

Shape-charges can be used underwater, but (i) the charge must be supported above the bottom a distance equal to the focus distance, and (ii) an air pocket is required in the space between the charge and the bottom. The charges, therefore, were fitted with sheet-metal stand-off tubes as shown in Figure 35. Divers filled the cavity below the charge with air after the charges were strapped in place in the template. Open stand-off tubes were used since completely sealed cavities would be required to withstand the total static pressure of the water.

Crater shaped holes, approximately two feet deep and four feet in diameter were made in the bottom of the Tarague Beach site using three ten-pound charges per hole. Failure of these charges to dig holes of smaller diameter and greater depth was blamed primarily on the air cavity beneath the charge. The tape seals between the charge and the stand-off tubes were not air tight and part of the air cavity was lost before the charges were detonated. The defective seals were not discovered until the charges were ready to be exploded, the filling of the air cavity being the last operation in preparing the charges. Divers noticed air bubbles escaping from the charges but decided against removing them to repair the seals.

Three small shaped-charges were used in the first trial to dig each hole, because it was reasoned that single charges would blast holes too small in diameter. This idea was abandoned after the Tarague Beach installation, even though the principle was not fairly tested because of the defective seals.

The tripod legs were cemented in the holes at Tarague Beach using the same procedure as described in the Orote Point installation.

C. Ylig Bay: The original plans for Ylig Bay called for the installation site to be located directly off the end of the Ylig Lava Spit (Figure 17). Soundings were made in the area which indicated that the bottom was very irregular and generally too deep. Reasonable soundings were obtained seaward of a large rock on the reef (later used as an anchor for the shore end of the instrument cable, Figure 20) to the south of the lava spit. Inspection of the bottom by divers at the time of the installation, however, indicated that it was very irregular and not suitable for the tripod. A level area was finally located south of the rock on the reef, where the tripod was installed. This change of location of the tripod accounts for the angle of the cable to the reef (Figure 17). The bottom shoreward of the tripod was irregular, but not cut by ditches as was the Tarague Beach reef. Instead this bottom was pocked by large holes with irregularities between. Some of the holes shoreward and north of the tripod were described by the divers as being twenty to fifty feet in diameter and thirty feet in depth.

At Ylig Bay holes for the tripod legs were blasted in the bottom with 40-pound shaped-charges (Figure 35) as described in the Tarague Beach tripod installation. Holes approximately two feet in diameter were dug to a depth of at least three feet. The holes were not cleared beyond this depth, even though it would have been possible. The tripod was cemented to the bottom, as described in the Orote Point tripod installation, with the exception that iron spikes were not driven into the sacks to bind them together. These spikes were not considered necessary because of the greater depth and small diameter of the holes blasted in the bottom.

Installation of Cables:

A. Orote Point: A suitable site for the pressure head could not be found on the Orote Point side of the harbor because of excessive bottom slope seaward of the point. A site, therefore, was selected for the instrument on the shoal area seaward of the breakwater where bottom conditions were acceptable and the instrument was well exposed to the sea. Another advantage of the site chosen was that the instrument could be installed approximately 800 feet from the breakwater. On the Orote Point side of the harbor entrance the instrument could have been installed only 100 feet from the cliffs. The expense of installing the 3000-foot cable across the harbor entrance, therefore, was justified by the better exposure of the instrument to the sea and the reduced exposure of the instrument to reflected waves.

The cable was routed around the harbor side of Orote Island (Figures 2 and 4) to take advantage of the reduced wave activity inside the harbor entrance. Along the cable path to the east of Orote Island, the reef was flat with an elevation of -1 to -3 feet MLLW shoreward of the reef face. The reef face extended eastward from the northeast tip of the island with a moderate slope to a depth of 10 to 15 feet. Smooth crevices, four to six feet in depth and four to ten feet in width scarred the reef face at approximately 25-foot intervals and

extended to depths of about ten to fifteen feet. The bottom seaward of the reef face sloped gently to a depth of 35 feet to the edge of an underwater cliff. At the other side of the harbor channel, the bottom sloped more uniformly to the instrument. No sudden changes in bottom slope were seen inside the ten fathom depth.

A cable was laid from a YTB tug with the cable spool mounted on the after deck in a standard cable spool trailer (Figure 7). A brake was added to the spool holder to maintain tension on the cable and to prevent the cable from unspooling under the weight of the cable between the ship and the bottom. The tug first was maneuvered about 400 feet from the reef face where a messenger line was shot to the reef with a line-throwing gun. The messenger line then was tied to a manila line, 3/4 inch in diameter, which in turn was tied to the armored electrical cable. Fifteen natives were hired to pull the messenger lines and the electrical cable from the tug to the reef. To reduce the cable drag, small buoys were tied to the electrical cable as it was pulled from the spool.

When enough cable had been pulled ashore to reach across the reef, the cable was secured to a large rock and the tug proceeded across the harbor channel laying the cable over the stern. When the tug reached the site of the tripod installation, mooring lines were run to the mooring buoys by a small craft and the tug was secured in position. The armor was then stripped off the end of the cable to provide a 75-foot "pig-tail" of light flexible cable. While the instrument was being attached to the pig-tail, divers bolted the end of the armored section of the cable to the tripod in the clips provided along one leg. Aboard the tug the instrument was bolted to a two foot tripod (Figure 47), with the flexible cable clamped in clips along one of its legs. The instrument and small tripod then were lowered to the divers who bolted the small tripod into place on the large tripod which had been previously installed. The 75 feet of flexible cable was coiled on horns welded at the top of the tripod ladder.

While the tug crew installed the instrument, a beach crew connected the shore end of the sea cable to a cable previously installed between the reef and the instrument hut located at the top of the cliff, shown in Figure 3. The typhoon-proof instrument hut was identical to the one used at the Ylig site (see Figure 19).

The Orote Point cable was inspected several days after its installation. This was done by swimming off the Orote Point reef at slack water and viewing the cable through face masks. The cable installation was satisfactory except for the section that crossed the reef face. Here the cable crossed several crevices at a slight angle and hung unsupported between their edges. As the waves passed, the cable swung back and forth, and it was immediately evident that excessive cable wear would take place at the edges of the crevices.

To correct this condition, divers chained the cable to a coral head on the bottom beyond the crevices. This prevented the cable from sliding down the underwater cliff when the shore end of the cable was released. The shore splice then was disconnected and the cable moved along the reef until its route paralleled the crevices. Swimmers then moved the cable into one of the crevices and pulled it taut. To hold the cable in place, two more chain anchors were attached to it, one on top of the reef and another at the shallow water end of the crevice. The shore end of the cable again was secured and connected to the recorder.

Three splices were made in the cable between Orote Island and Orote Point, Figure 2. Two of these splices were necessary to remove defective sections of the cable between the reef and the instrument while the third splice connected the cliff cable to the sea cable.

B. Tarague Beach and Ylig Bay: The cables were installed at Tarague Beach and Ylig Bay using a technique different than that used at Orote Point. At these sites the installation procedure was complicated by the need of securely anchoring the instrument cables to the reef face to prevent wear or breakage of the cable by heavy seas. The waves acting on these reefs peaked up at a distance of less than one-hundred feet from the reef and broke directly on the reef face. The locations of the instruments and the general set-up for the installation at Tarague Beach are shown in Figures 8-16 , and for Ylig Bay in Figures 17-23.

By installing the cables in the crevices which extended across the reef face, the cables were not required to withstand the direct force of the breaking waves. However, they were required to withstand large forces due to the turbulence caused by waves and due to the surge currents present in the crevices. The weight and strength of the armored electrical cable was not considered sufficient to withstand these forces. Both weight and strength were added by lashing the electrical cable to $1\frac{1}{2}$-inch chain (18 pounds per foot) as shown in Figures 16 and 21. The armored cable first was attached to the chain with rings made of 3/8-inch diameter iron rod and then tightly lashed with seizing wire. The iron rings were used to bind the chain and cable together; the seizing wire prevented the electrical cable from being snagged on the bottom during installation. Three hundred and sixty feet of chain was used to reinforce the cable along the section that extended 100 feet shoreward, and 260 feet seaward of the reef face.

On the day the cable was installed, buoys were brought to the reef and attached to the chain and cable. Fifty-five-gallon buoys were attached at seventy-five-foot intervals to support the electrical cable, and three hundred-gallon buoys were attached at seventy-five-foot intervals to support the chain as shown schematically in Figure 38. The small buoys were tied to the electrical cable with manila rope that was cut to free the buoys after the cable was pulled into position. The large buoys were attached to the chain by steel cable straps which first were passed through the bottom eye of the buoy, and then attached to the top eye with a pelican hook. When the chain was pulled into position the pelican hook was tripped, allowing the strap to run through the bottom eye to free the chain from the buoy.

The chain was pulled off the reef by the diving tug as follows (Figures 41 and 42). A messenger line was shot to the reef and was used to pull a 1/2-inch diameter manila line off the tug to the reef. This line was tied to the end of the electrical cable and was used to pull the buoyed cable off the reef. A second line then was shot to the reef and was used to pull a four-inch (circumference) manila line to the reef. The four-inch line was used to pull a 3/4-inch steel cable off the reef to the tug. The steel cable, attached to the end of the chain, was used to pull the chain off the reef with the tug's capstan. While the chain was being pulled off the reef the electrical cable was kept taut at all times. This prevented the sections of cable between the buoys from touching bottom and becoming snagged. When all the cable and chain was pulled off the reef, the buoys were cut free, and the cable dropped to the bottom. Then the armor was stripped from the end

of the cable to provide a 75-foot "pig-tail" of light flexible cable. This was then handled in the same manner as was the Orote Point installation. As can be seen in Figures 8 and 9, armored telephone cable and standard telephone cable was run from the beach (Figures 8 and 14) to the Tarague Pump Station. As this installation was typhoon proof no special shelter had to be provided. The recording equipment was placed in the Pump Station (Figures 10-13).

In Figures 17 and 18 are shown the general layout at the Ylig Bay site. A cable splice was made on the reef (Figure 22) and armored telephone cable was run from the beach to the highway where the recording equipment was installed in a typhoon proof instrument hut transported to this location (Figure 19)*.

MARK IX PRESSURE HEAD

The pressure heads initially installed at the three locations at Guam were the Mark IX, Model 4 (Figures 49 and 50). This pressure head is made up of a differential pressure transducer, a pressure averaging system, and a protective housing. The heart of the gage, the Bournes differential pressure transducer, consists of a pressure sensitive bellows linked to the moving wiper arm of an accurately wound 750-ohm potentiometer[5]. The wiper at zero differential pressure rests at the middle of the resistance winding. When a differential pressure is applied to the bellows, the wiper departs from this position a distance proportional to the applied pressure difference. This change in wiper position is converted to a proportional current in an electronically stabilized bridge circuit and is recorded on a recording milliammeter. To insure long life of the potentiometer, the resistance winding is submerged in oil.

A pressure averaging system supplies a pressure to balance the pressure of the water at the depth of installation, and also to balance the changes in depth caused by tides. This system results in a wave pressure record which is not confused by tidal pressure variations. The averaging circuit consists of the air filled transducer dome of the pressure head, which acts as a capacitor, and a capillary tube which acts as a resistance between the dome and an oil filled rubber bellows exposed to the water pressure. The resistance capacitance combination filters out the rapidly fluctuating wave pressure from the relatively static pressure of depth and tide. This filtered pressure is applied to one side of the transducer bellows, while a pressure equal to the actual water pressure is applied to the other side. The transducer measures the difference, which is the wave pressure. The metal chamber, open at the bottom, which surrounds the rubber bellows, supports the bellows when it is initially pressurized so that it does not burst.

Since the allowable change in volume of the rubber bellows is small compared to the total volume of the gage, it is necessary to pressurize the gage before installation to prevent total collapse of the rubber bellows when water pressure is applied. Pressurizing to 60 percent of the absolute pressure at the expected depth of installation is done with an ordinary tire pump through the valve opening in the transducer chamber.

The connection box over the transducer dome provides a simple method of connecting the instrument to the underwater cable. "Fusite" fused glass to metal seals feed the electrical circuit from the transducer chamber to the connection chamber. The seals are necessary because the pressure in the connection chamber is always near atmospheric pressure, while the transducer

* The typhoon proof huts at Ylig Bay and Orote Point were ones originally used for a previous study of the waves in Apra Harbor. See Reference 1.

chamber is at the static water level pressure. The electric cable enters the chamber through a tapered sleeve where it is securely clamped. Waterproofing of the connection sleeve is accomplished by wrapping with rubber tape and rubber cement.

SHORE RECORDING EQUIPMENT

The onshore equipment units used in the Mark IX Shore Wave Recording System consists of (a) the Power Supply and Bridge Unit, and (b) the Esterline-Angus Recording Milliammeter. The following description will be concerned with the former.

Power Supply and Bridge Circuit:

As the name implies, the unit performs two functions. These functions are: (a) the supply of regulated d-c power to the measuring circuit, and (b) the conversion of the mechanical position of the potentiometer arm in the underwater instrument to a proportional electrical current sufficient to drive the recording milliammeter. In Figure 51 is shown the complete unit.

Regulated d-c voltage is derived from 60-cycle a-c input voltage by passing it through a full wave rectifier, a choke input filter and a voltage regulator. The voltage regulator is a series-shunt type, having for its reference a 22½-volt battery. The regulator circuit (Figure 52) functions in such a way as to maintain a given ratio between the output voltage and the reference voltage.

The reference battery operates without load current and consequently has a life equal to the shelf life of a battery. A second battery, used as a bias in the grid circuit of the series tube, also operates at zero load. These batteries should be replaced approximately once a year or whenever the current adjustment control on the front panel can no longer be set to provide the correct bridge current.

Sangamo Timer: The timer, driven by a self-starting, synchronous motor, is connected directly across the a-c input line, hence it is in continuous operation regardless of the power switch position. The programming dial can be seen through the window provided in the case. The protective case cover may be removed for adjustment of the programming cams. Two cams are used in fixing the duration of the fast and slow speed runs. Each of these cams (Figure 53) have four arms spaced 90° apart to provide six-hour intervals; (other intervals can be obtained by cutting cams with more or less than the four arms mentioned here). The duration of the fast run may be fixed to a minimum of 15 minutes by careful angular positioning of the "on" and "off" cams with respect to each other. They are securely clamped in place on the shank of the hub provided.

In addition to automatic programming of the chart speed, a manual speed shift lever is provided which extends through a slot in the cover of the timer. This lever will shift the chart to the fast speed during any portion of the slow speed intervals for additional fast sampling during storm periods. This lever should not be operated if the next fast-speed run is scheduled in less than two hours (minimum off time 2 hours).

The dial of the timer may be set for the time of day by rotating it clockwise until the correct time is aligned with the red pointer located just below the dial.

Power Switch: With the power switch open, the only element in operation is the Sangamo timer. The rest of the circuit is inoperative, including the chart movement, the power to the measuring circuit, the shift mechanism and the warning circuit. When the power switch is closed, the unit will operate according to the programming selected (see "Programming Switches").

Selector Switch: The Model III bridge and power supply unit provides for two pressure heads installed at different locations, or at the same location with one unit as a stand-by. Either pressure head may be operated individually. The selector switch is provided to bring one unit or the other into the bridge circuit. The two pressure heads (if two are used) are wired to the bridge circuit with one conductor common.

Warning Light: The purpose of the warning light is to give a visual indication of the fact that the chart roll is nearing depletion, and that the Easterline-Angus recorder should be provided with a new roll.

The Esterline-Angus recorder has been modified to include a switch that is placed behind the chart roll. When the chart roll diameter reaches the warning dimensions, the warning circuit is closed. One relay contact functions in parallel with the switch to prevent contact arcing and in order for the warning circuit to function, subsequent to a previous warning, it is necessary to interrupt the warning circuit by pushing the reset button provided just below the warning light on the front panel, after the new roll has been placed in the recorder.

If desired, an audible warning device, such as a buzzer, may be placed in the circuit by connecting it across the light terminals on the rear terminal board.

Bridge Current Control: To adjust the bridge current, turn the potentiometer control knob (cw for increasing, ccw for decreasing) until the bridge current is 32 ma. The bridge milliammeter is located just above this potentiometer control knob on the front panel. The purpose of this adjustment is to provide the correct current in the Bourns Differential Pressure Potentiometer. The output voltage to the bridge circuit is made sufficient by the above adjustment to compensate for the line drop in the cable from the bridge to the pressure head. The "current adjustment" is actually an adjustment of the regulated d-c voltage.

Range Switch: Two measuring sensitivities are built into the bridge circuit. The range switch may be placed in either of two positions corresponding to full scale deflections of 7½ and 15 feet of water, respectively.

Sensitivity Adjustment: As seen in the circuit diagram (Figure 52) rheostats are placed in series with the range resistors. The purpose, location and application of these rheostats are given below. Hereafter, they will be known as sensitivity adjustments.

The dial skirt knobs to the sensitivity adjustment rheostats are located within the Bridge and Power Supply cabinet. By varying the resistance in series with the range resistors, fine adjustments are made to correct for: (a) the change in sensitivity of the bellows-potentiometer transducer, due to the effect of an entrapped air dome, and (b) variations in the manufacturer's specification of the potentiometer. A sensitivity adjustment graph has been

prepared and mounted on the inside of the cabinet lid, giving a dial setting to be applied for given conditions of depth of installation (air dome correction) and actual potentiometer resistance.

The advantage of this adjustment is that regardless of depth and actual potentiometer resistance (within the limits of the adjustment) full scale calibrations of 5 feet and 10 feet pressure variation can be obtained. There will be slight variations in the correct sensitivity setting caused by variable tides and stages. This error is well within the allowable experimental error expected in analysis of the subsurface pressure records.

Programming Switches: These switches are located within the cabinet. S_1 is the power programming switch, S_2 is the chart drive (clock) programming switch.

(a) Normal Programming: In normal programming the Sangamo timer actuates only the magnetic speed shift of the recorder chart drive. With the S_2 switch in position "N", the clock chart drive runs continuously; with the S_1 switch in the "N" position, power is being supplied to the bridge circuit continuously. Switches S_1 and S_2 are shown in Figure 52. The resulting record consists of a series of fast speed and slow speed intervals showing the time history of the wave action during both speeds. As mentioned before, the time durations of these fast chart speed runs and slow chart speed runs depend upon the positioning of the timer cams in the Sangamo timer.

(b) Power Programming with Continuous Chart Movement: The power is programmed in that it is being supplied to the measuring circuit during the fast speed portion of the record only. The record obtained using the power programming with continuous chart movement is satisfactory for determining wave height and period but does not enable a determination of storm arrivals.

Normally, a complete and continuous record is desired for analysis purposes. Formerly, the reason for this type of programming was to extend the life of the potentiometers used in the Mark III type pressure gages. This was accomplished by shutting off the power to the potentiometer and allowing the contact arm to wipe the windings "clean". The potentiometer used in the Mark IX is a more rugged model than the one used in the Mark III, and this procedure should not be necessary solely for attempting to extend the life of the potentiometer.

The switching necessary to effect this type of programming is as follows: S_1 is in position "P" so that the power will be supplied to the pressure head according to the timer schedule; S_2 is placed in position "N" which gives continuous chart movement (when the main power switch is on). The resulting record consists of a series of fast chart speed intervals with the recorded time history of the wave action. During the slow chart speed portion, a straight line appears centered on the chart record .

(c) Power Programming with Discontinuous Chart Movement: This alternative method of programming is essentially the same as the one mentioned above, except the clock chart drive is also programmed. The chart is driven only during the fast speed interval. The switching necessary to effect this type of programming is as

follows: As before, the switch S_1 is in position "P", switch S_2 is also in position "P". The record consists of a series of fast speed runs giving the time history of the wave action during this period only.

SWITCHING SUMMARY OF RECORD PROGRAMMING METHODS

ITEM DESCRIPTION	POWER SWITCH	S_1			S_2	
		N	P		N	P
(1) Normal programming	On	✓			✓	
(2) Power programming with continuous chart movement	On		✓		✓	
(3) Power programming with discontinuous chart movement	On		✓			✓

Fuses: As noted in the circuit diagram, one 2-amp. and three 1/16-amp. fuses provide overload protection. The 2-amp fuse provides protection to the input circuit, and the 1/16 fuses, located in each line of the bridge circuit, provide protection to the pressure head itself.

Terminal Board Wiring: All external connections to the bridge and power supply are made on the main terminal board on the back side of the cabinet. Five terminals are provided for the pressure head cable with the " - " lead common. The pressure head's fusite terminals are stamped with " + " , " - " and "CT" (center tap) so that with color coded conductors, there should be little confusion in making the correct connections between the pressure heads and the bridge unit.

Two other sets of terminals include the plus and minus recorder terminals connected to corresponding binding posts on the Esterline-Angus recorder, and the auxiliary 24 d-c terminals. The latter may be used in either of two situations.

(a) In case of unavailability or failure of a-c power source, the bridge power may be supplied by dry cell batteries. The only drain on the battery supply would be the total bridge current (56 ma.). When batteries are used, the regulator circuit is inoperative, since the filaments of the tubes are not being supplied with power.

(b) It may be desirable to use additional capacity of the power supply to operate a complimentary instrument (such as a direction indicator). Current may be drawn from the power supply through these connections (100 milliamperes maximum), in addition to that required by the pressure head.

The chart warning, shift, clock and a-c common terminals are connected to corresponding terminals on the Esterline-Angus recorder with an a-c common connection to one post of each circuit.

The "light" connection is provided to operate warning circuits external to the bridge unit (like the aforementioned buzzer). Whenever the chart warning light on the front panel is "on", this terminal will be energized with 110 volts a-c.

Esterline-Angus Recorder:

The instrument used to construct a graphic record is the Esterline-Angus direct current milliammeter. The metering element of this instrument is a permanent magnet, moving coil type. The instrument is housed in a portable case. The writing pen, which is mounted on knife edges and which pivots about bearings, is supplied by ink fed to the point by capillary action. A center zero calibration is used, the range being plus and minus 0.5 milliamperes.

Chart drives for 110 volts, 220 volts, or 440 volts, at any commercial frequency may be furnished as follows:

(a) Slow and rapid speed eight-day spring clock giving all speeds; 3/4, 1½, 3, 6, and 12 inches per hour and inches per minute.

(b) Slow and rapid speed synchronous motor clock giving all chart speeds, 3/4, 1½, 3, 6, and 12 inches per hour and inches per minute.

For use in conjunction with an automatic programming cam, a magnetic gear shift can be employed with the synchronous motor clocks. With this device, the shift from hourly speeds to minute speeds and vice versa may be controlled automatically according to the programming schedule used. In addition to being actuated by the cam, a manual control is available for shifting the chart speed. For the Guam installation, the unit was programmed to run at fast speed (3 inches per minute) for twenty minutes every six hours. It ran at 3 inches per hour during the remainder of the time.

Telemetering System to Central Recording Station:

Telemetering of the wave recorder signal was accomplished by simply connecting the telephone lines between the output of the Mark IX bridge at the shore site and the Esterline-Angus recorder at the recording station. The telephone lines were jumpered around all switching units, amplifiers and impedance matching devices at the telephone exchanges, and therefore consisted of only a two-conductor cable between the beach site and the recording station.

The resistance of the telephone lines was used as a part of the total Esterline-Angus series resistance which controls the sensitivity of the recorder. A potentiometer connected in series between the telephone line and the Esterline-Angus recorder at the central recording station therefore served as a sensitivity control and was adjusted to obtain the desired full scale recording at the recording station.

An automatic switching system was included in the telemetering system. In case of a failure of either the telephone lines or the 110-volt power system, a battery power supply and a spring driven Esterline-Angus recorder was switched into operation in place of an electric power supply and the remote Esterline-Angus recorder.

As can be seen in the block diagram of Figure 54, the relay operated switches were driven by a thyratron control tube which in effect had two input signals. The first was the 110-volt power at the shore station, which supplied power to the circuit, and the second was a 60-cycle signal transmitted through the telephone line from the recording station to the shore station, which supplied a positive bias to the thyratron tube. Failure of either of the signals would cause the relay to be de-energized and would switch the circuit to the

position shown in Figure 54. The 60-cycle signal did not interfere with the wave recorder signal in any way. A very slight vibration of the Esterline-Angus pen could be noted, but this vibration did nothing more than reduce the paper friction.

SERVICING

The servicing of the equipment is not covered herein, as it has been presented in a subsequent report:[4]

Guam Shore Wave Recorder Installation: II
M. A. Hall and R. L. Wiegel
Technical Report: Series 3, Issue 354
Institute of Engineering Research
University of Calif., Berkeley, Calif.
July, 1953.

ACKNOWLEDGMENTS

The author wishes to acknowledge the work of R. L. Wiegel in helping to prepare certain sections of this report. He further wishes to acknowledge the work of his colleagues M. A. Hall and R. L. Wiegel in the survey, installation and maintenance of the equipment. Additional thanks are due M. Lincoln for preparing the illustrations and E. Henderson for typing the manuscript.

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1. Chinn, A.J. and Winkler, E.M., Summary report on wave measurements of Apra Harbor, Guam, M.I. Series 26, Issue 3, IER., University of Calif. Berkeley, Calif., August 1950.

2. Dinger, J.E., and Fisher, G.H., Microseism and ocean wave studies on Guam; Naval Research Lab., NRL Memo Report 205, 20 August 1953.

3. Folsom, R.G., Measurement of ocean waves; Trans. Amer. Geophys. Union, vol. 30, No. 5, pp. 691-699, Oct. 1949.

4. Hall, M.A. and Wiegel, R.L., Guam shore wave recorder installation: II; Series 3, Issue 354, IER, Univ. of Calif, Berkeley, Calif., July 1953.

5. Snodgrass, F.E. and Stiling, D.E., Operation manual for Mark IX shore wave recording system; Series 3, Issue 320, IER, Univ. of Calif., Berkeley, Calif., Sept. 1952.

6. Wiegel, R.L., Gravity waves, tables of functions; Council on Wave Research, The Engineering Foundation, 30 pp, Feb. 1954.

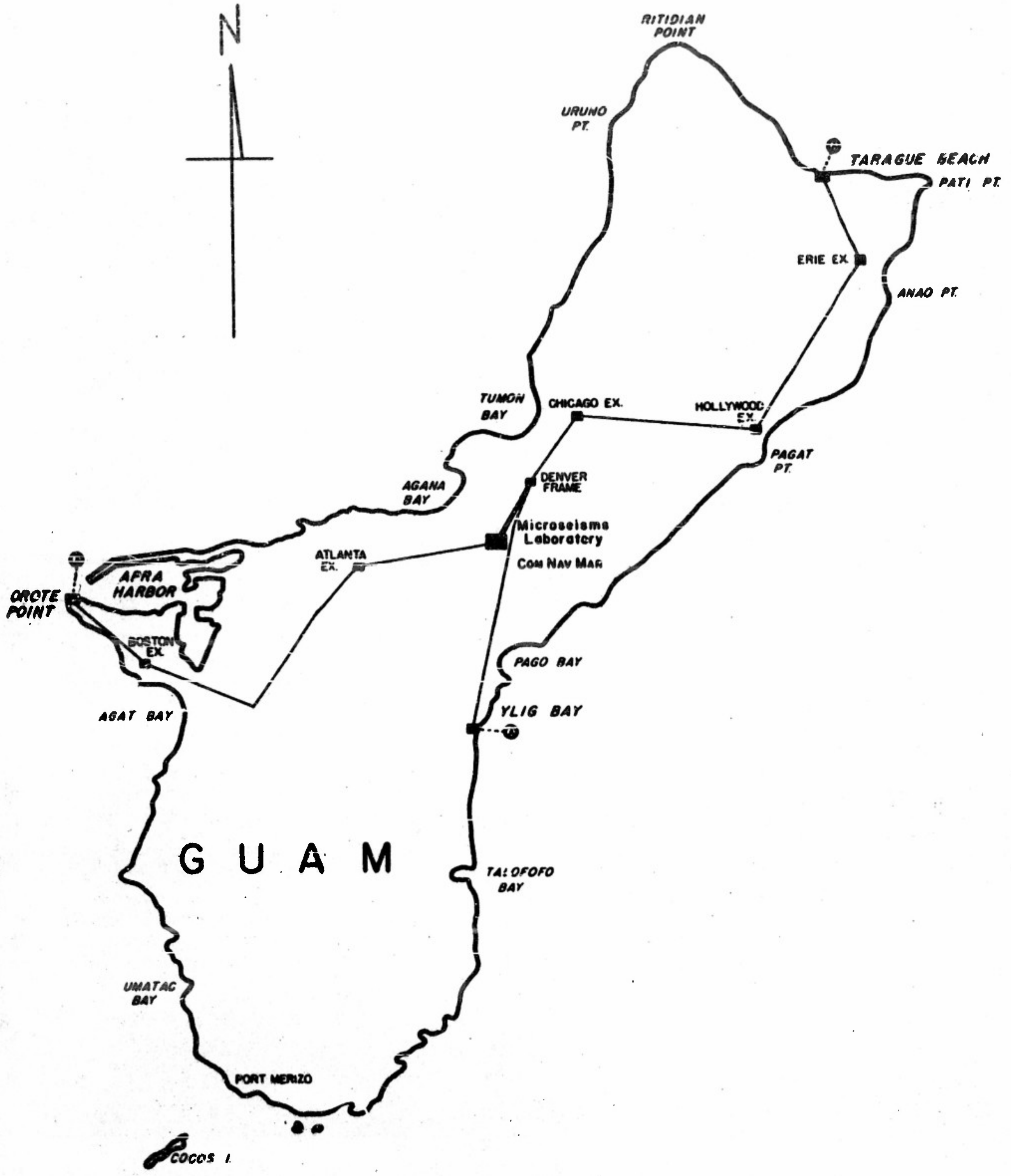


Fig. 1 - Location of wave recording instruments and telephone telemetering lines at Guam

HYD-6210

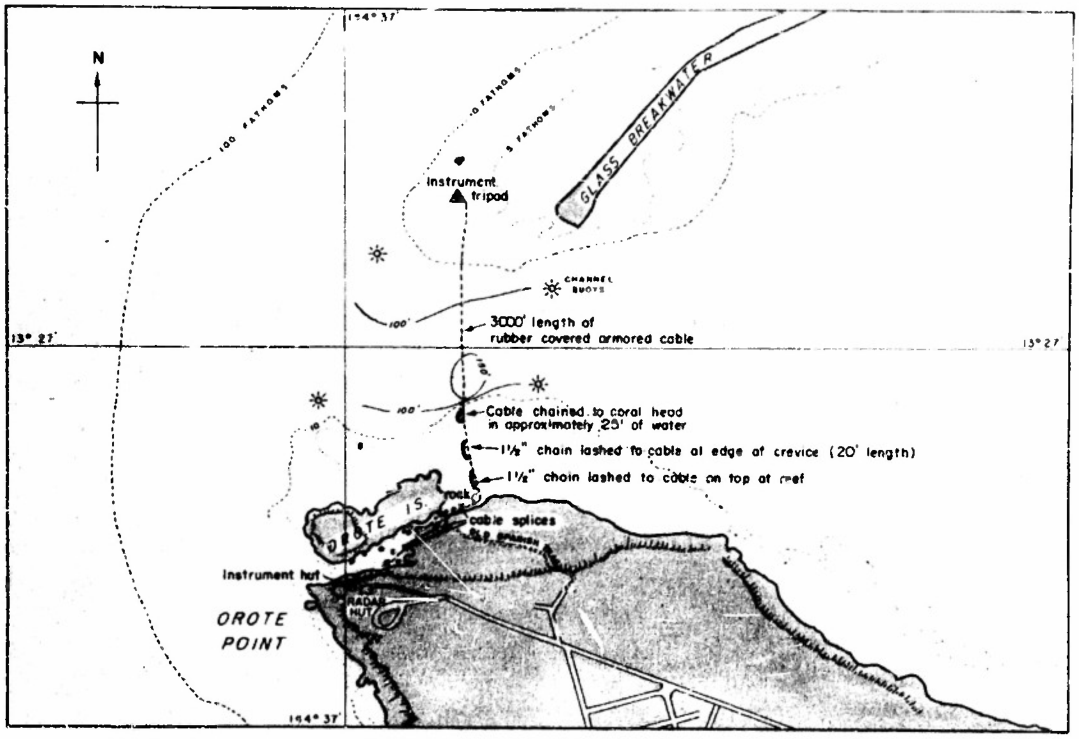


Fig. 2 - Schematic diagram of complete installation at Orote Point

Fig. 3 - Laying cable in cove between Orote Point and Orote Island

Fig. 4 - Aerial view of Orote Point and Apra Harbor

Fig. 5 - Orote Point as seen from instrument site

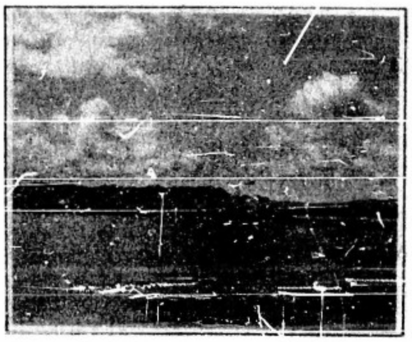


Fig. 6 - End of breakwater and landfall from instrument site

Fig. 7 - Loading cable aboard YTB

OROTE POINT INSTALLATION

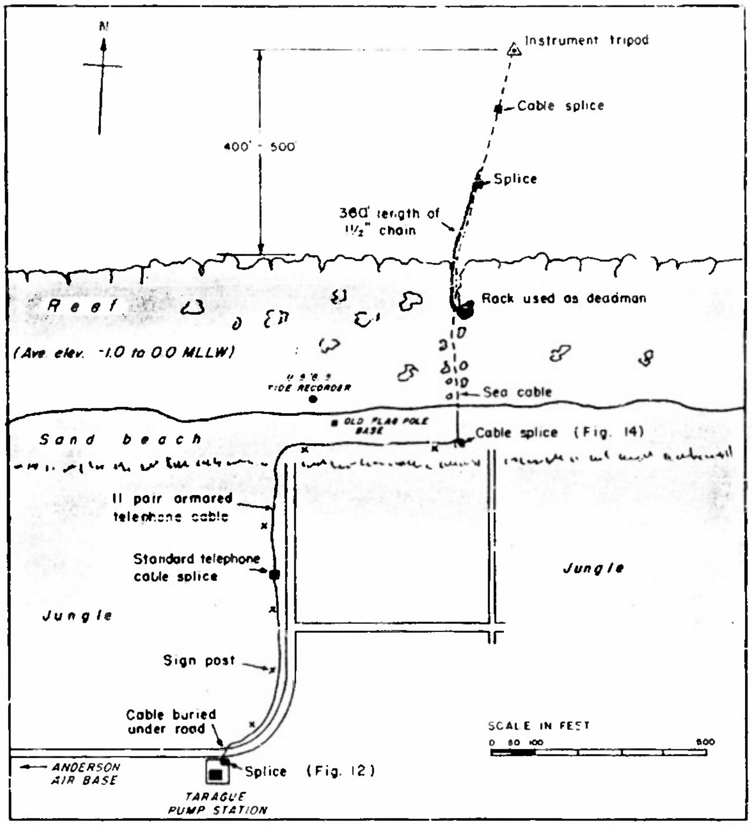


Fig. 8 - Schematic diagram of completed installation at Tarague Beach

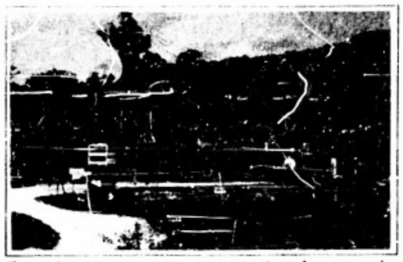


Fig. 10 - Tarague pump station from road

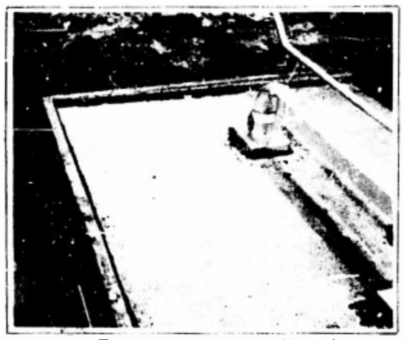


Fig. 11 - Tarague pump station house from edge of well

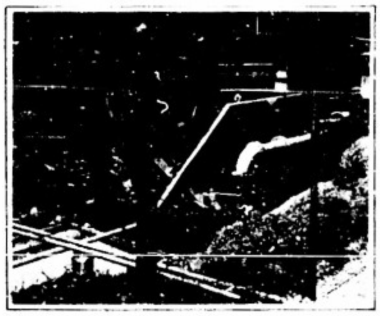


Fig. 12 - Cable splice at well

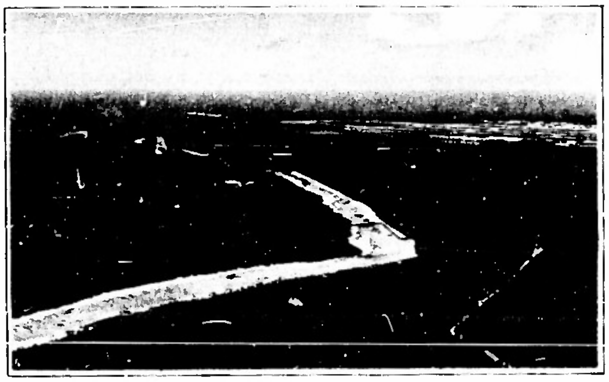


Fig. 9 - Aerial view of Tarague Beach

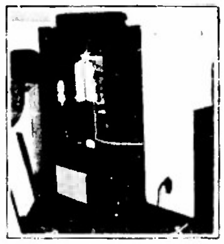


Fig. 13 - Instruments in pump house

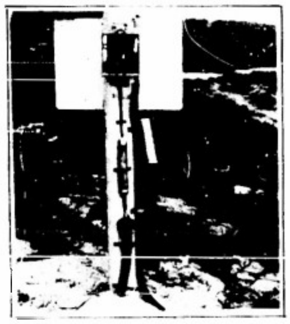


Fig. 14 - Cable splice on beach

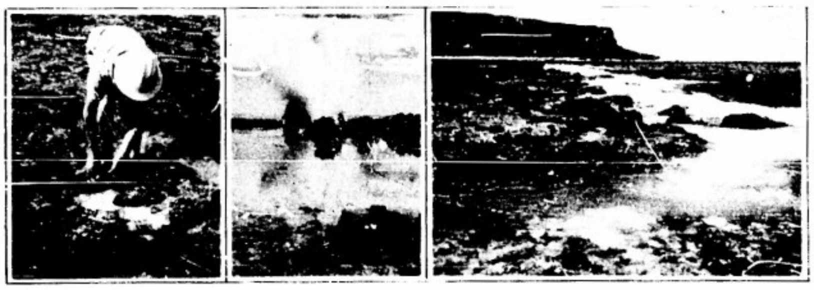


Fig. 15 - Blasting coral heads to clear a crevice for electrical cable

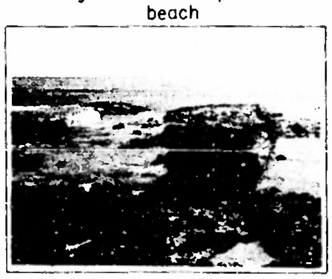


Fig. 16 - Edge of reef

TARAGUE BEACH INSTALLATION

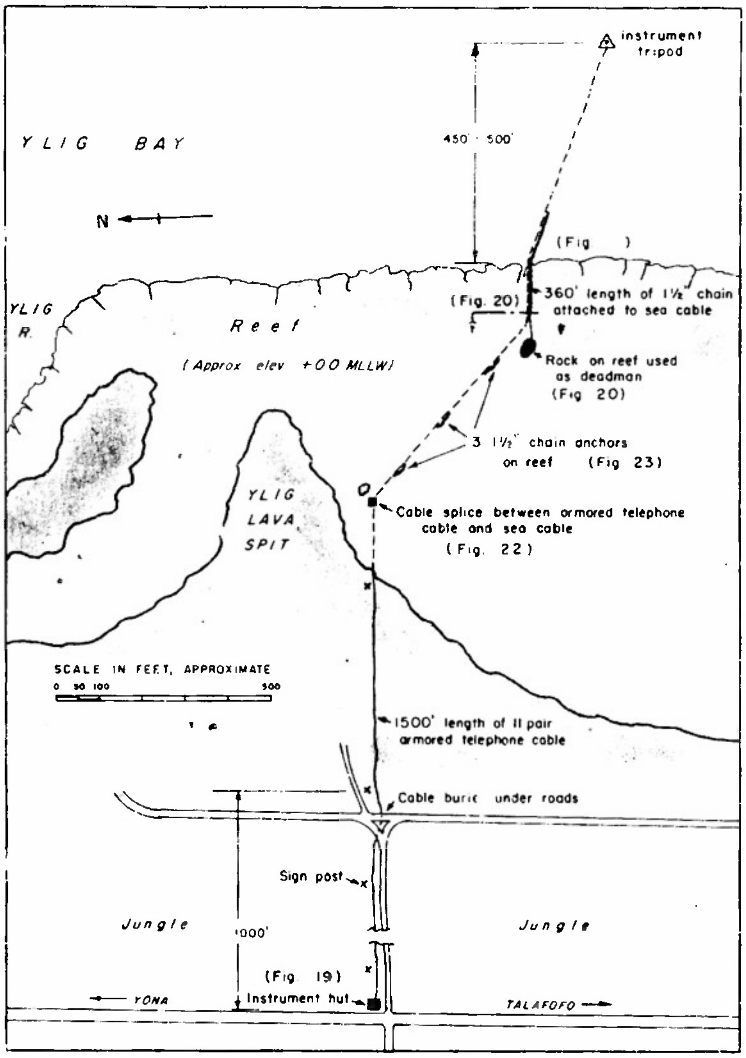


Fig 17 - Schematic diagram of the completed installation at Ylig Bay

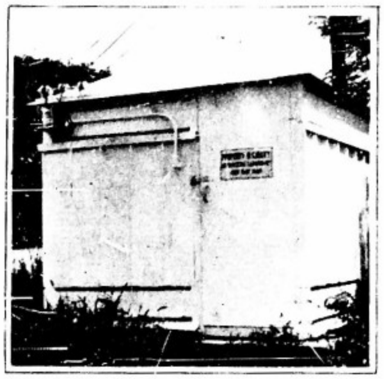


Fig 19 - Instrument hut

Fig 20 - Ylig Bay reef at low tide

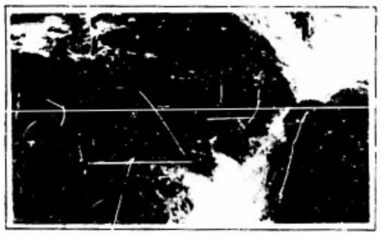


Fig 21 - Cable at edge of reef

Fig 22 - Cable splice on reef

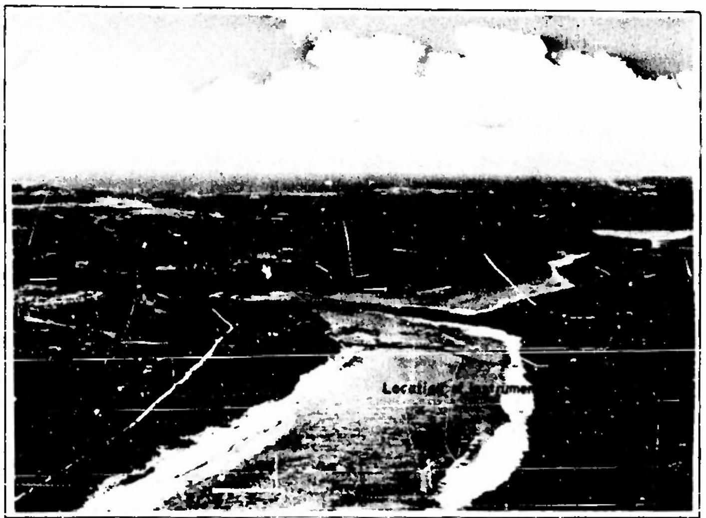


Fig 18 - Aerial view of Ylig Bay; channel through reef at center caused by fresh water flow of Ylig River

Fig 23 - Chain anchors on reef

YLIG BAY INSTALLATION

FIGURES 17 - 23

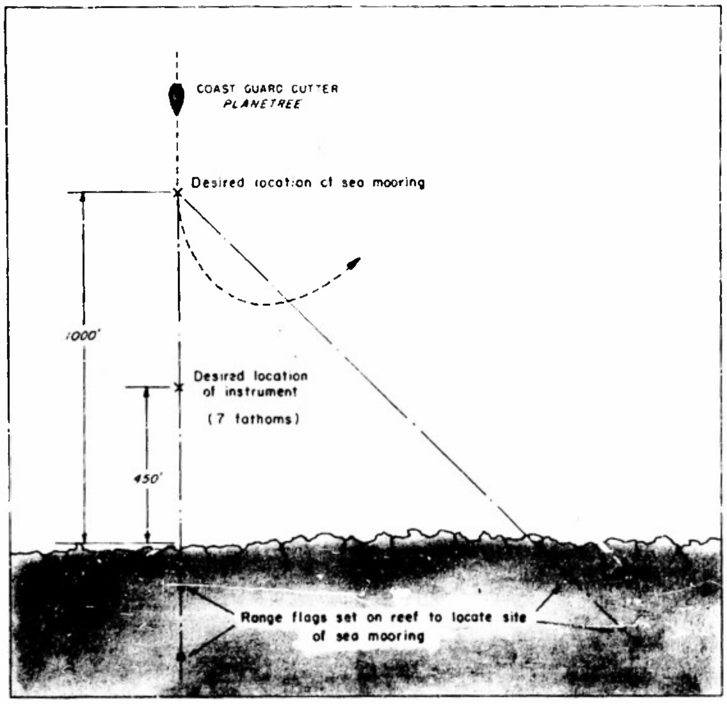


Fig. 24 - Schematic diagram of the escort ship laying the sea mooring for the diving tug

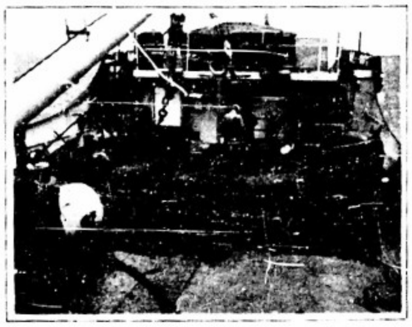


Fig. 26 - Mooring anchor, chain and buoys assembled on deck of Coast Guard cutter

Fig. 27 - Preparing to drop mooring at Ylig Bay; note anchor suspended over side of ship

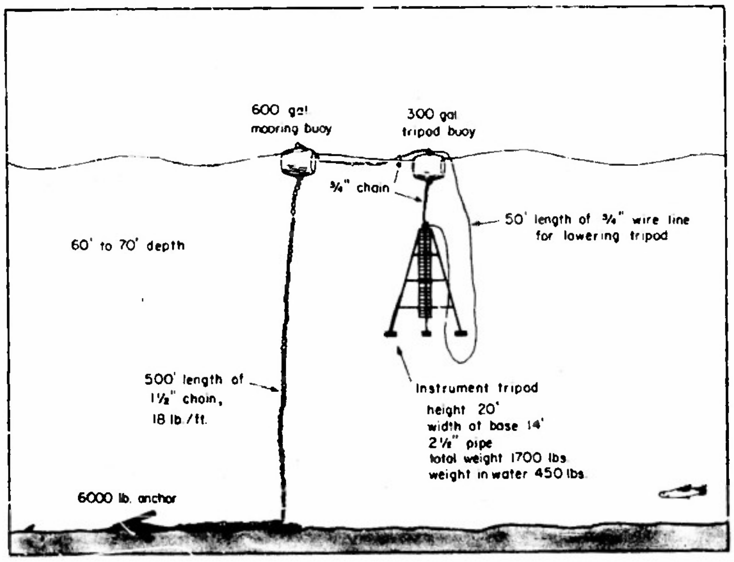


Fig. 25 - Schematic diagram of the sea mooring and buoyed tripod left by the escort ship

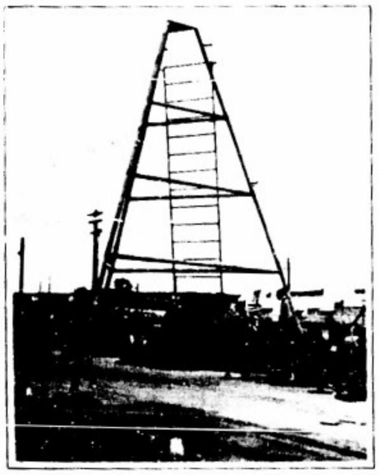


Fig. 28 - Pressure head tripod; note cable clamps along one leg and cable horns near top of ladder

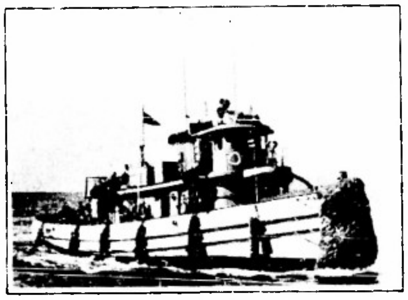


Fig. 29 - The YTB (yard tug big) used for all work close to reef

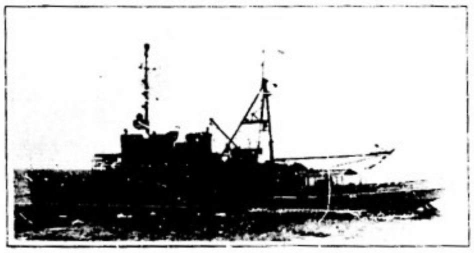


Fig. 30 - The ATF (auxiliary tug fleet) used as an escort ship

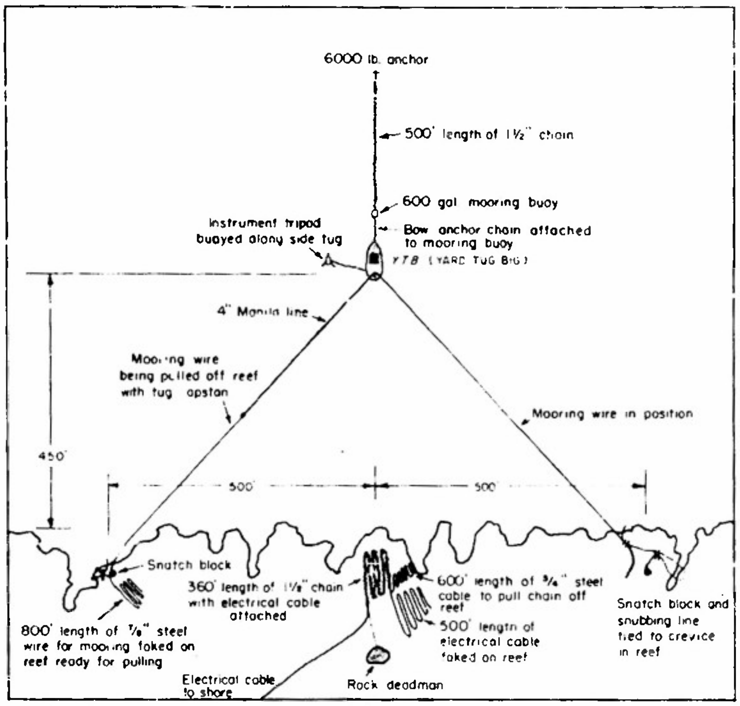


Fig. 31 - Schematic diagram of the diving tug moored in position with all cables and chain made ready on reef

Fig 32 - Mooring line being pulled into position of Ylig Bay

Fig 33 - 4-inch Manila pulling line being tied to ⅞" diameter steel mooring line on reef

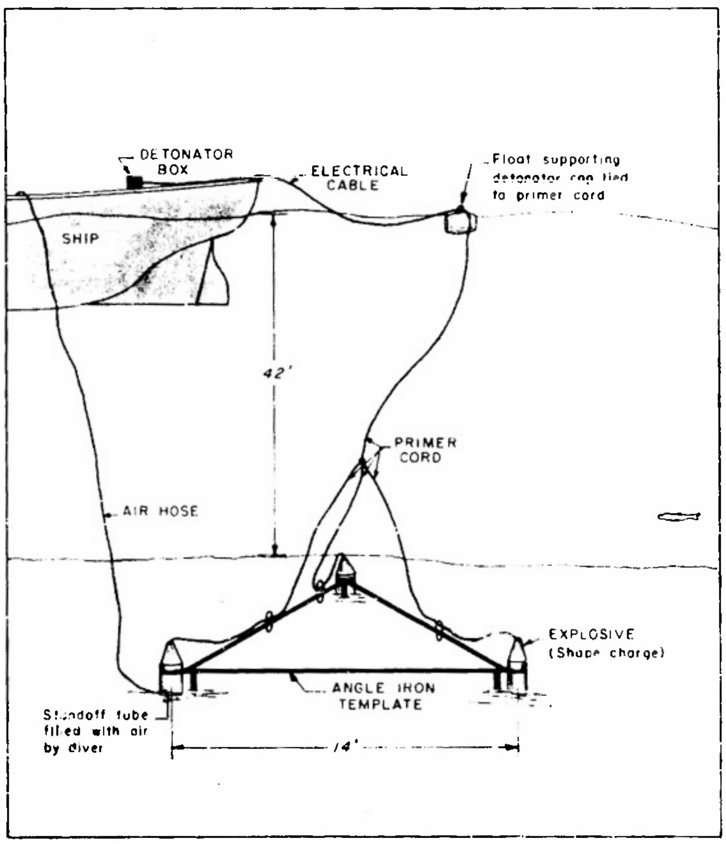


Fig. 34 - Schematic diagram of shaped charges installed on bottom ready for detonation

Fig 35 - Attaching stand-off tube to shaped charge

Fig 36 - Diver taking explosive to bottom

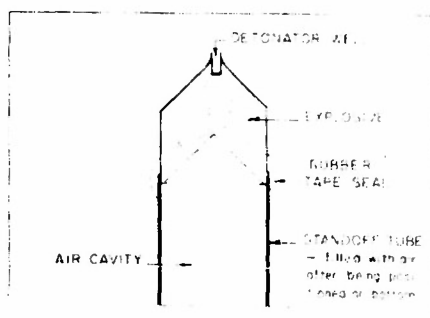


Fig 37 - Schematic diagram of the shaped charge and stand-off tube assembly

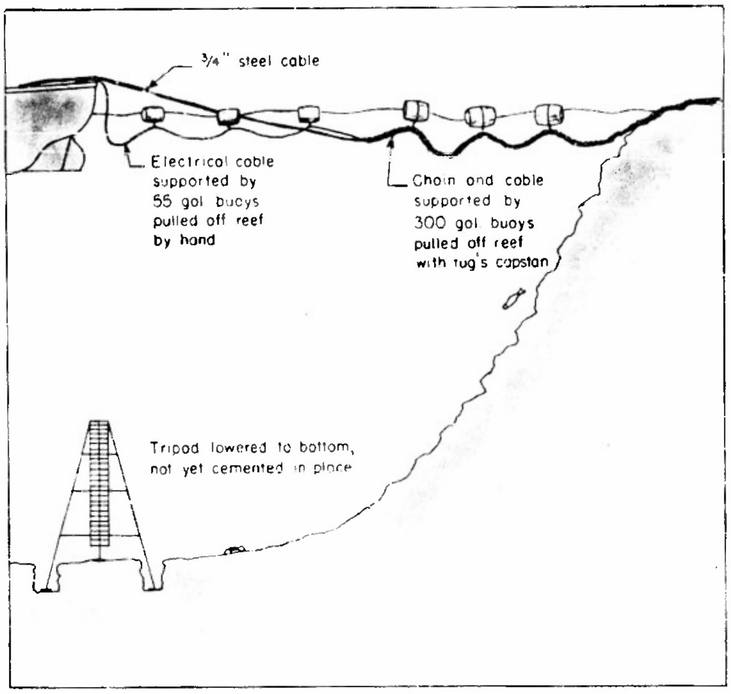


Fig. 38 - Schematic diagram of technique used to install cable at Ylig Bay

Fig. 39 - Diver in deep sea dress; note double lead belt

Fig. 40 - Laying cable through jungle

Fig. 41 - Pulling cable off reef

Fig. 42 - Electrical cable and chain being pulled off reef at Ylig Bay

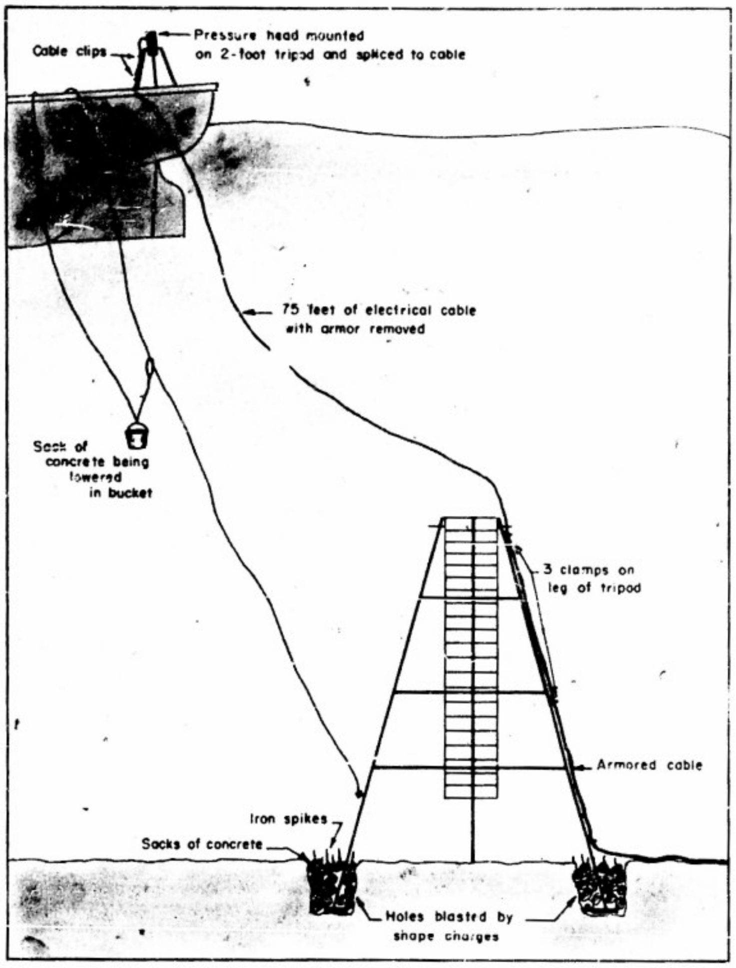


Fig 43 - Schematic diagram of cementing tripod to bottom and splicing pressure head to cable

Fig. 44 - Mixing concrete

Fig 45 - Sacking concrete

Fig. 46 - Lowering sacks of concrete to diver

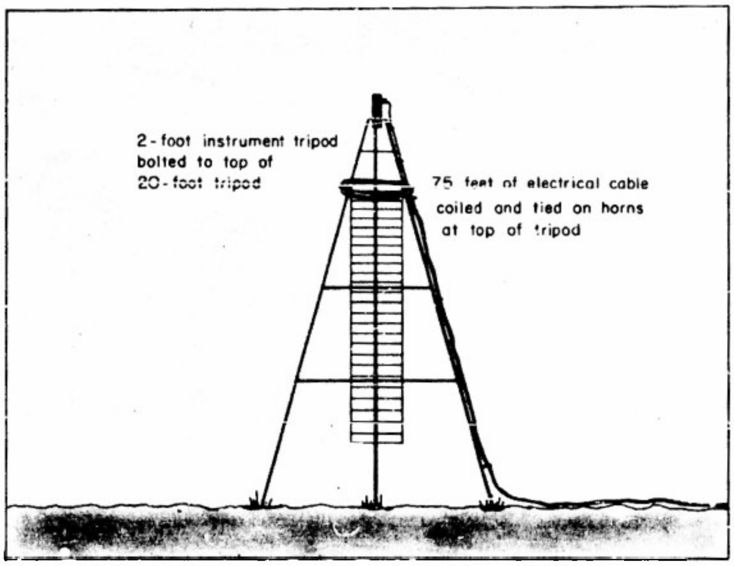
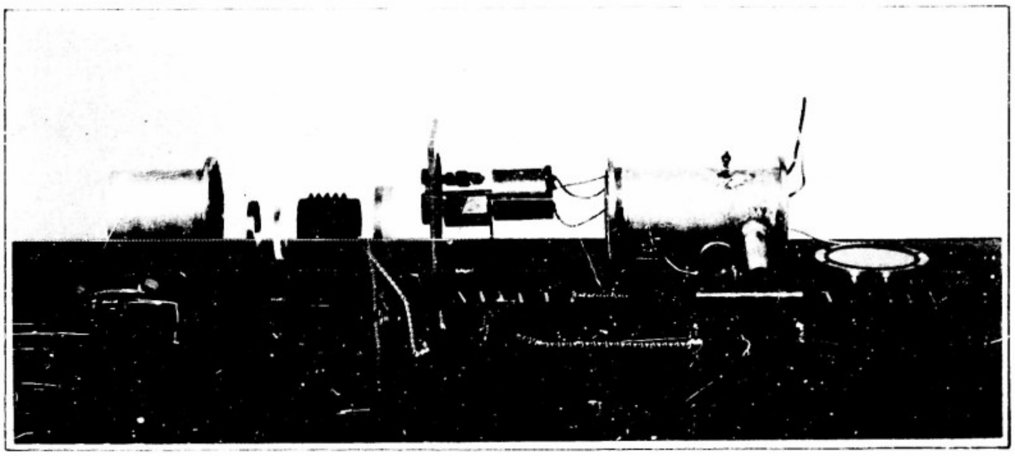
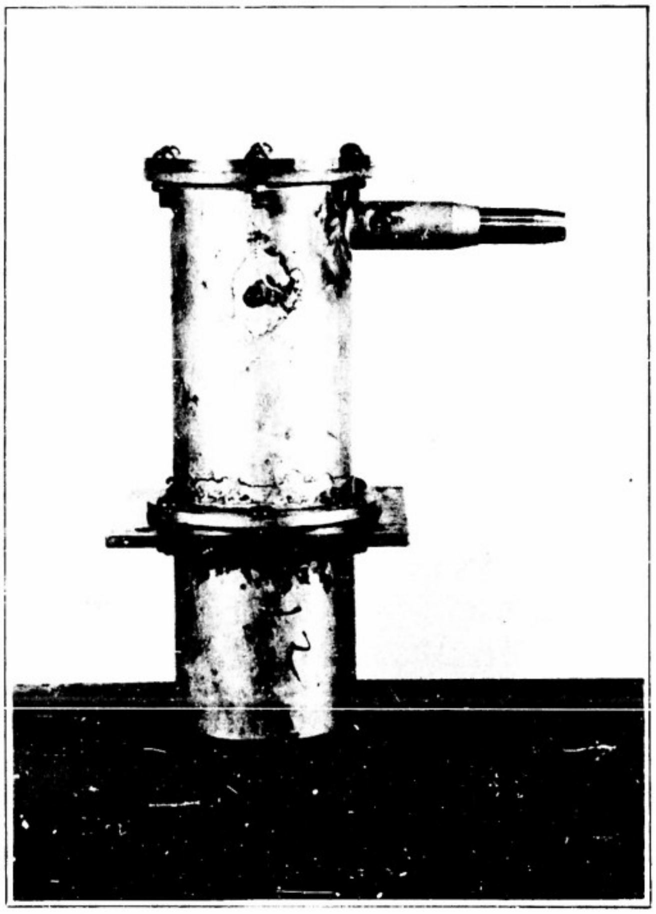


Fig 48 - Schematic diagram of the installed pressure head and tripod

Fig 47 - Preparing to splice pressure head to cable



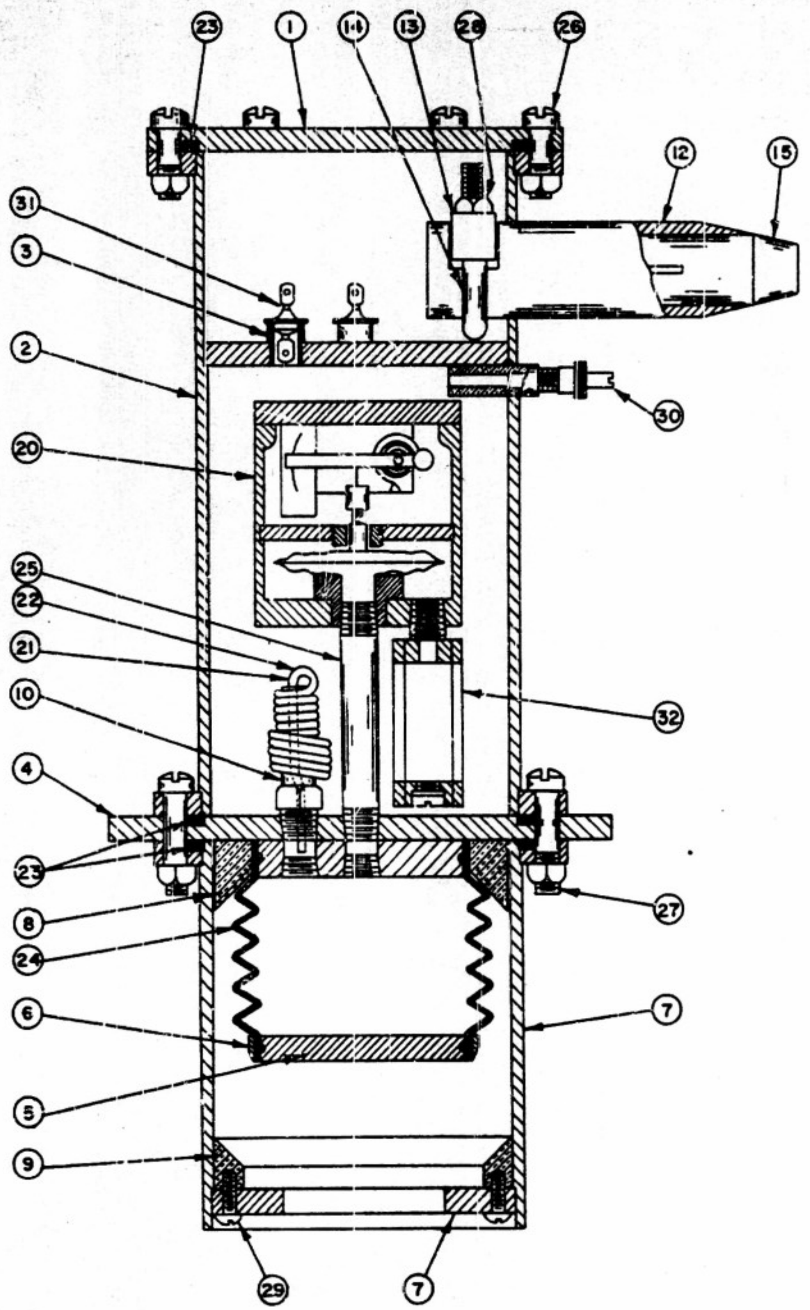
a. Exploded view



b. Assembled view

MARK IX DIFFERENTIAL PRESSURE GAGE

FIGURE 49

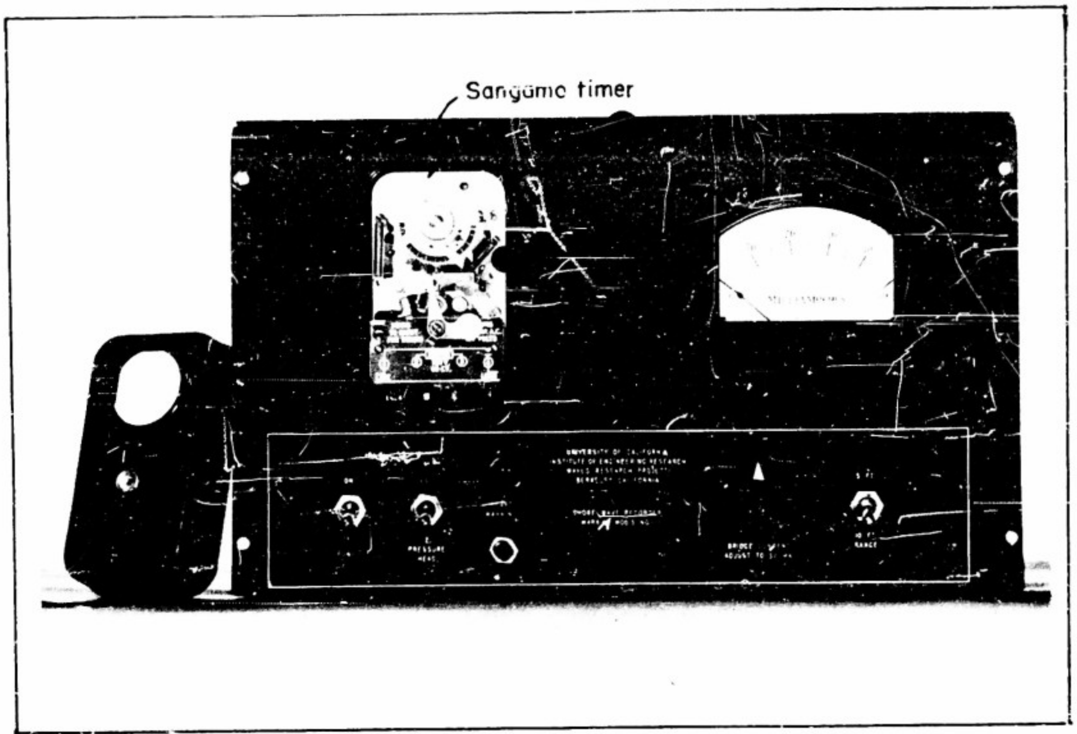


ITEM NO.	PARTS DESCRIPTION
1	Connection chamber cover
2	Transducer chamber
3	Fusite mounts
4	Mounting plate
5	Bellows end plate
6	Lower bellows clamp
7	Bellows chamber
8	Upper bellows clamp
9	Bellows support ring
10	Slow leak mount
12	Cable connector
13	Cable sleeve clamp
14	" " "
15	Cable sleeve
20	Bourns potentiometer #503
21	#110 capillary tubing 29" long
22	#24 (.020") wire inside #110 capillary tubing
23	"O" ring-linear #1866-16
24	Rubber bellows
25	1/8 brass pipe 2 1/2" long
26	1/4 - 28 x 3/4 filister head & nut
27	1/4 - 28 x 1 filister head & nut
28	1/4 - 28 nut
29	8 - 32 x 7/16 RHMS
30	Schrader valve (truck valve) & cap
31	Fusite connectors #112-FP
32	Diaphragm mount

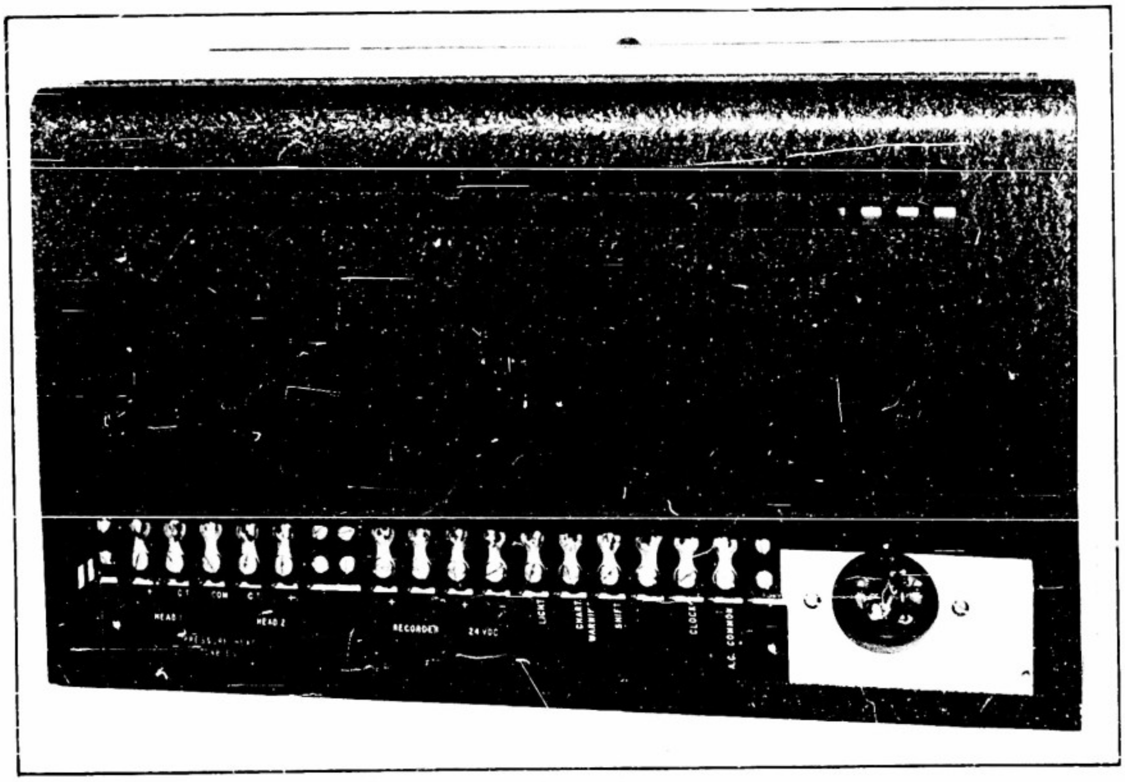
MARK IX, MODEL 4, PRESSURE HEAD

HYD-6556

FIGURE 50



A. FRONT PANEL (Note program cams)



B. BACK PANEL (Terminal board)

MARK IX, MODEL III BRIDGE AND POWER SUPPLY UNIT

FIGURE 51

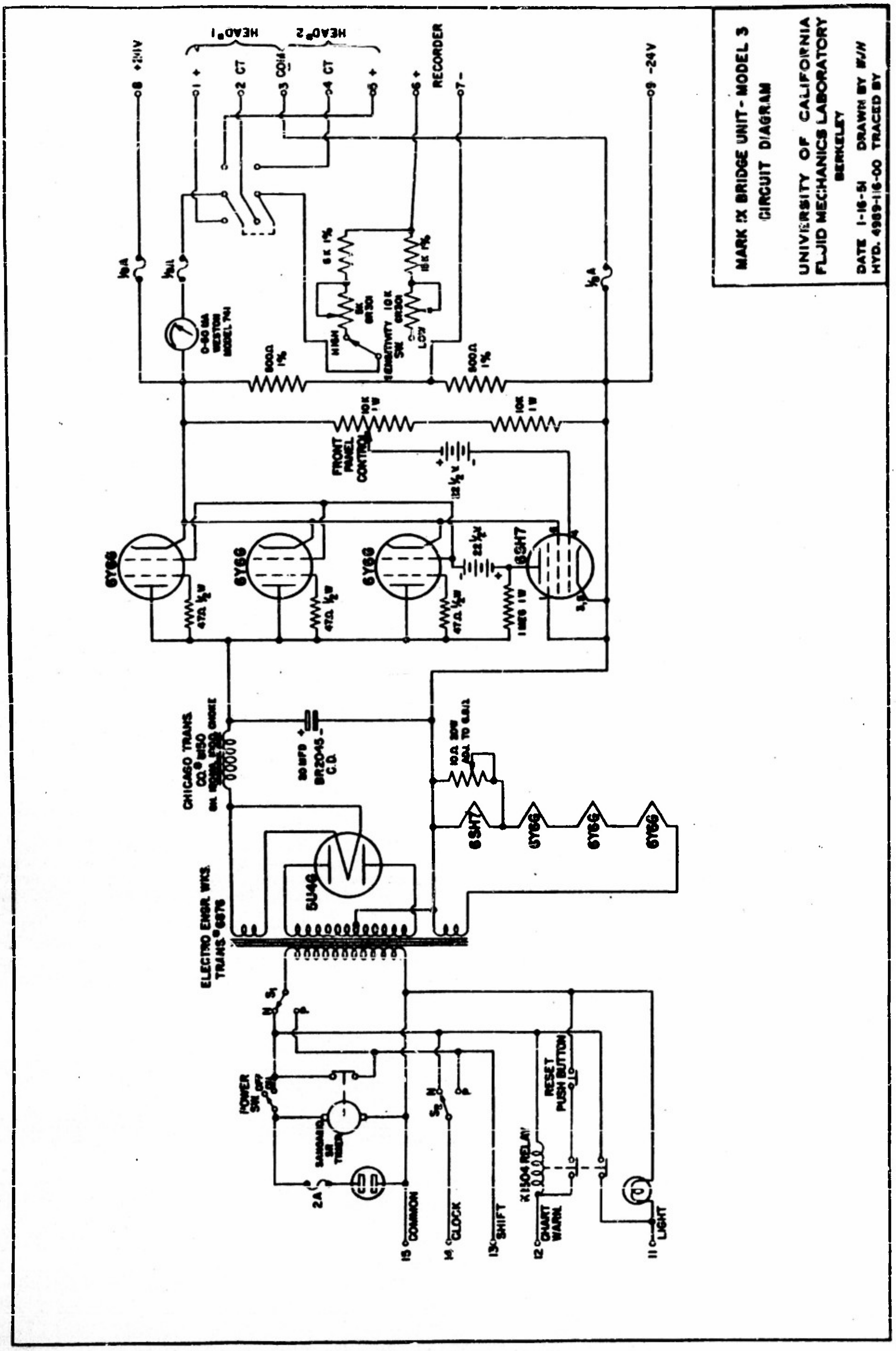

MARK IX BRIDGE UNIT - MODEL 3
CIRCUIT DIAGRAM
UNIVERSITY OF CALIFORNIA
FLUID MECHANICS LABORATORY
BERKELEY
DATE 1-16-51
DRAWN BY W/H
HYD. 4989-116-00
TRACED BY
RECORDER
HEAD 1
HEAD 2
FRONT PANEL CONTROL
6Y6G
6SH7
5U4G
CHICAGO TRANS.
ELECTRO ENGR. WKS. TRANS.
RESET PUSH BUTTON
POWER SW.
COMMON
CLOCK
SHIFT
CHART WARN.
LIGHT

FIGURE 52

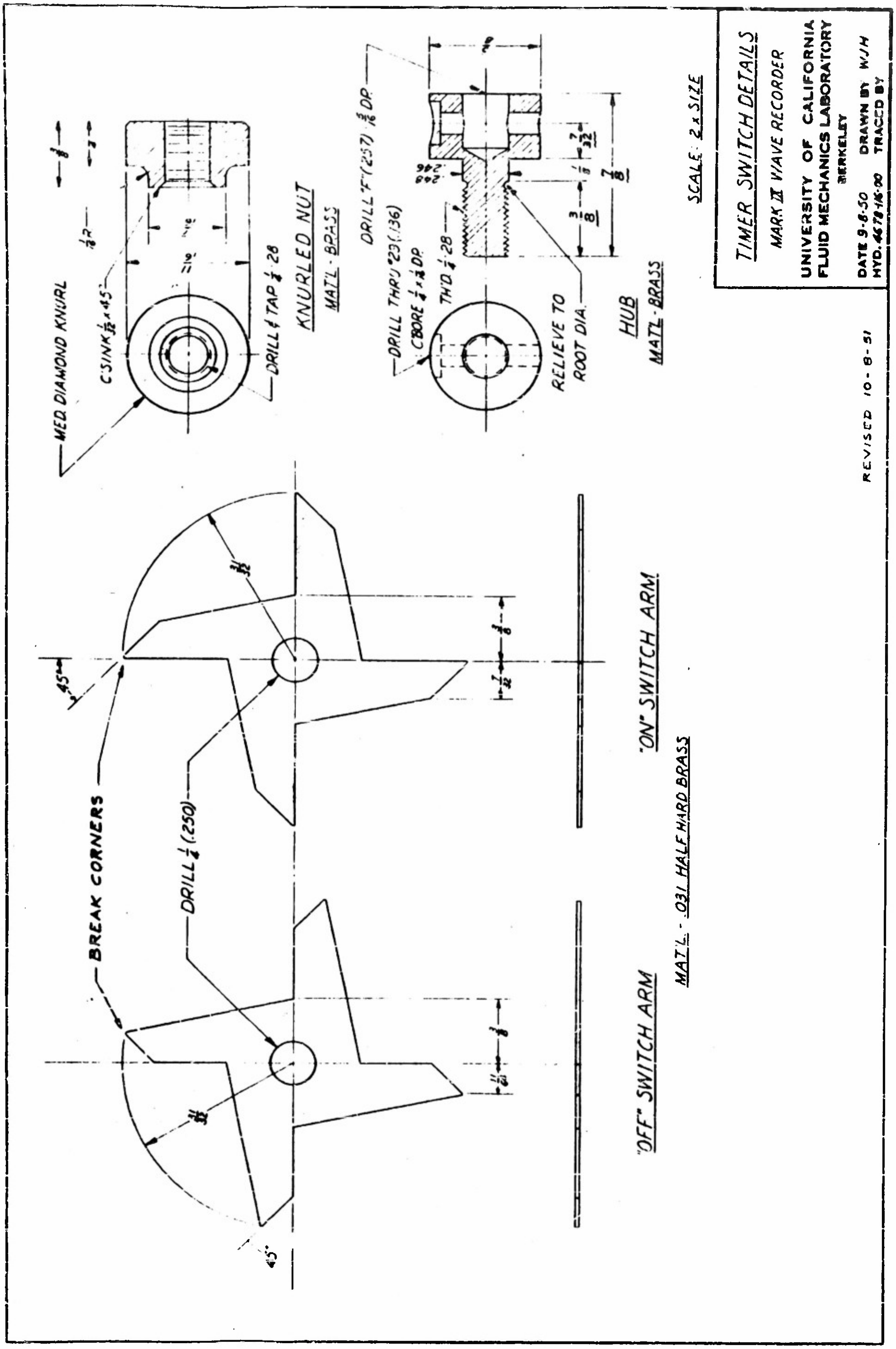
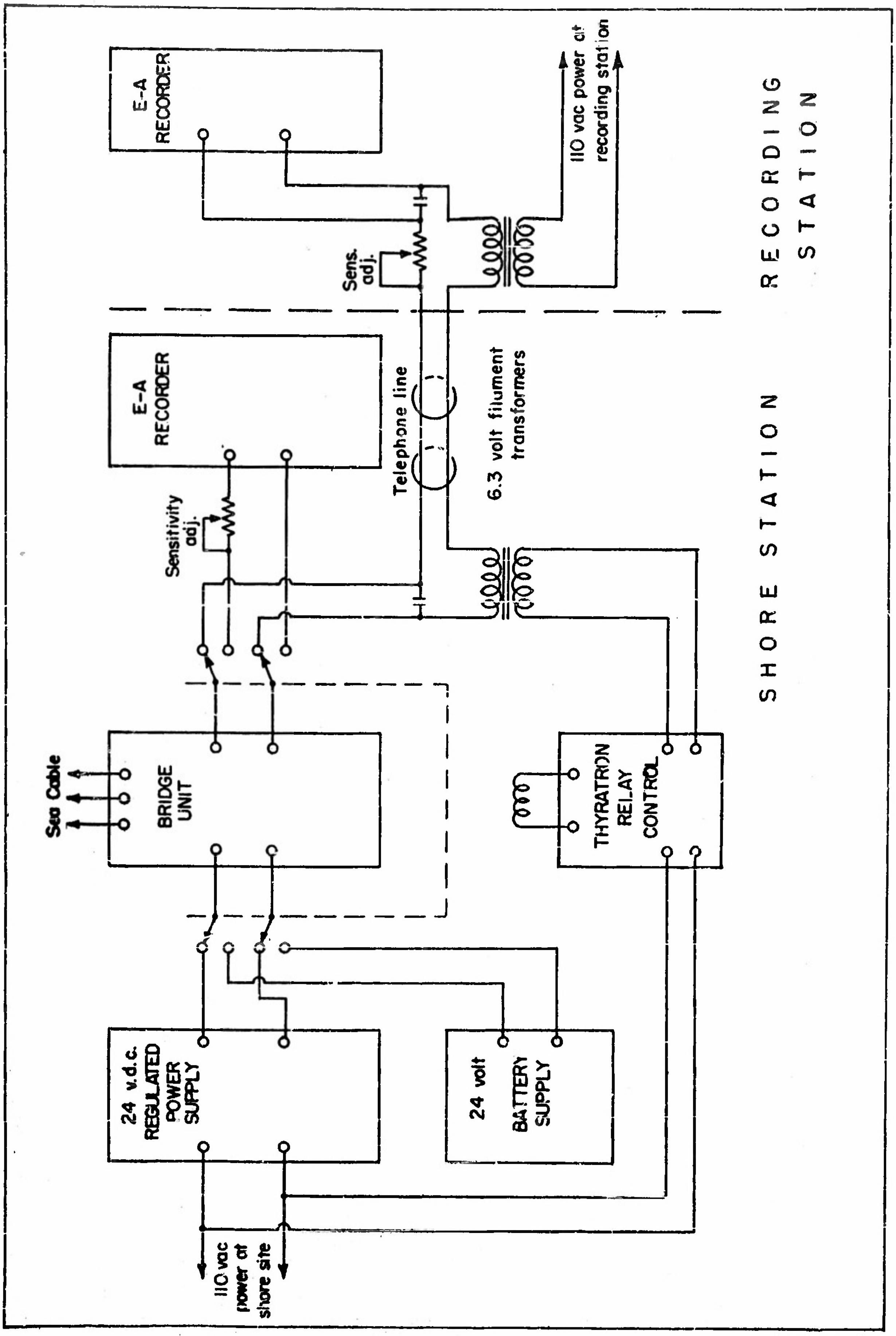
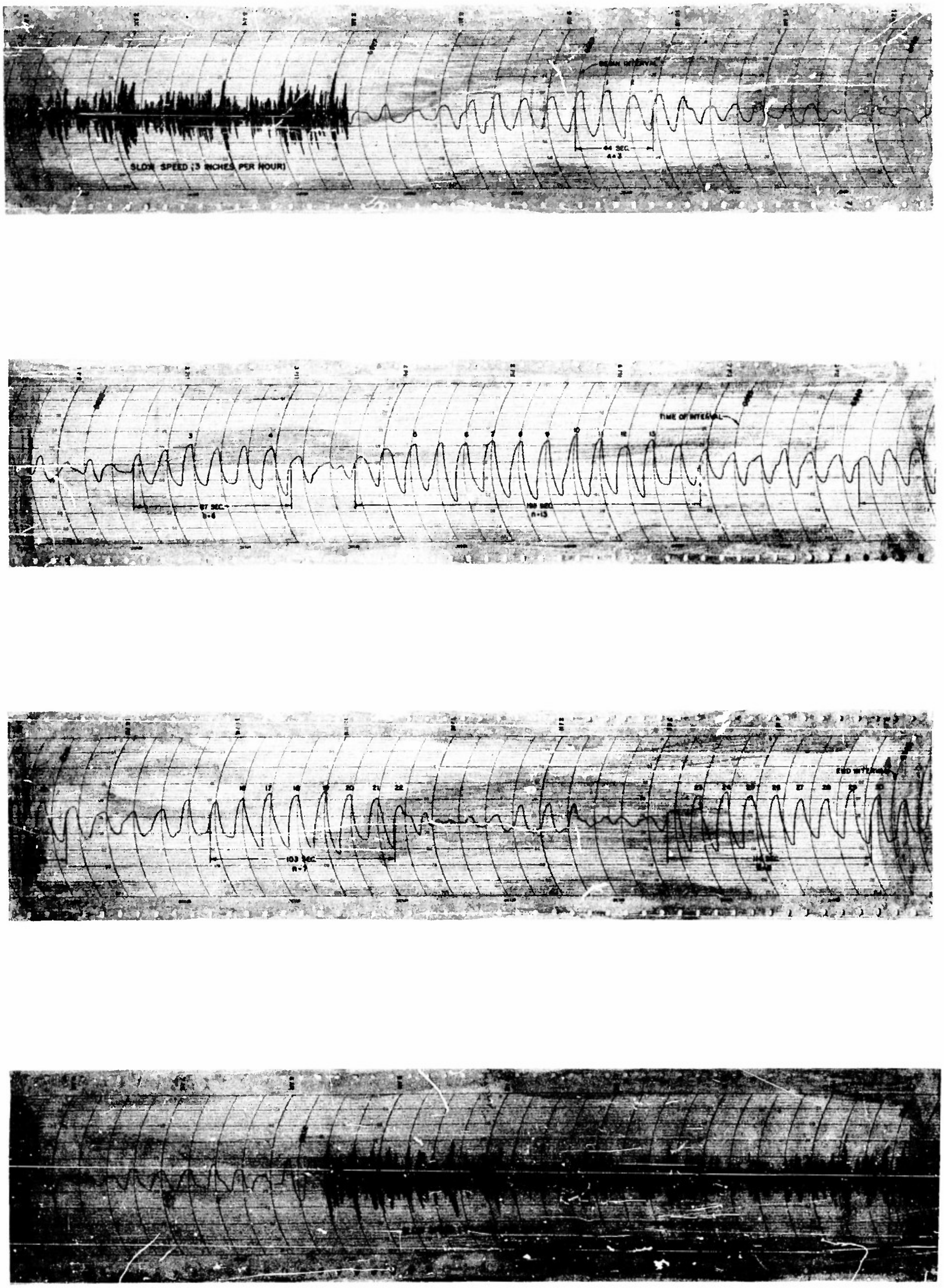

TIMER SWITCH DETAILS
MARK II WAVE RECORDER
UNIVERSITY OF CALIFORNIA
FLUID MECHANICS LABORATORY
BERKELEY
DATE 9-6-50
DRAWN BY WJH
TRACED BY
REVISED 10-8-51
SCALE: 2x SIZE
MED DIAMOND KNURL
DRILL & TAP 1/4-28
KNURLED NUT
MAT'L - BRASS
DRILL "F" (.257) 3/16 DP.
DRILL THRU #23 (.136)
TH'D 1/4-28
RELIEVE TO ROOT DIA.
HUB
MAT'L - BRASS
BREAK CORNERS
DRILL 1/4 (.250)
45°
"ON" SWITCH ARM
"OFF" SWITCH ARM
MAT'L - .031 HALF HARD BRASS

FIGURE 53



E-A RECORDER
110 vac power at recording station
Sens. adj.
RECORDING STATION
E-A RECORDER
Telephone line
6.3 volt filament transformers
Sensitivity adj.
SHORE STATION
Sea Cable
BRIDGE UNIT
THYRATRON RELAY CONTROL
24 v.d.c. REGULATED POWER SUPPLY
24 volt BATTERY SUPPLY
110 vac power at shore site

FIGURE 54



SAMPLE WAVE RECORD ANALYSIS

APPENDIX I

ANALYSIS OF OCEAN WAVE RECORDS

The wave recorders are programmed to run at slow-speed (3 inches per hour) for 5 hours and 40 minutes, and at fast-speed (3 inches per minute) for 20 minutes. When definite and pronounced increases in wave amplitudes (indicating the arrival of wave trains) are evident on the slow-speed portion of the record, the time and date of these arrivals are noted by the analyzer. Only the fast-speed sections of the chart are analyzed for wave height and period. A twenty-minute interval is selected for determining characteristic wave period and maximum and characteristic wave heights. Except in cases of storm arrivals, as previously mentioned, the records are analyzed at twelve-hour intervals. Records are analyzed every six hours during storm periods or when the slow speed portion of the record indicates rapidly changing conditions.

To standardize practices used in the analysis of ocean waves from under-water pressure-head records, the following list of definitions has been accepted(3)*.

1. Wave height is the vertical distance between the crest of a wave and the preceding trough.

2. Characteristic wave height is the average height of 33-1/3 percent of the highest waves.

3. Wave period is the time interval between the appearance at a fixed point of successive wave crests.

4. Characteristic wave period is the average period for the well-defined series of highest waves recorded.

5. Wave direction is the orientation of the line of travel of the largest well-defined waves.

PROCEDURE FOR ANALYZING WAVE RECORDS

The following steps in the procedure for analyzing wave records have been developed over a period of several years at the University of California.

Receipt of the Record:

The graphic chart represents the time history of the surface wave action and should be the final authority in case of future conjecture as to the validity of statistical information compiled therefrom. Hence, a system of logging charts is used for facility of future reference. The log of records contains: (a) the time and date the run began and ended, (b) the number of the chart (i.e., its chronological sequence) and (c) the date the record was received. Following is a form which has been used for logging records.

LOCATION		START		END		REMARKS
RECEIVED	ROLL NO.	TIME	DATE	TIME	DATE	

Log for Mark IX Wave Recorder Charts

* Superscript numbers in parentheses refer to References at end of main body of report.

Reading the Chart:

A. Frequency of taking samples

1. The wave records are analyzed during the fast-speed portion of the chart at approximately twelve-hour intervals. Recorders are programmed to obtain fast-speed records at 6 A.M., noon, 6 P.M., and midnight.*

2. Manual operation of the chart speed is provided on all records. Additional samples may be obtained by the operator during storm periods. The frequency of these samples and the number of the records analyzed is left to the discretion of the operator and analyst.

B. Establishing the point in time of readings

1. The beginning time should always be marked on the chart when a new roll is placed in operation, and also when it is removed from the recorder.

2. If possible, time checks should be made on the chart during the recording period together with supplementary remarks concerning the character of the surface waves.**

3. A progressive time determination is made assuming six-hour intervals between the beginnings of the fast-speed runs. The time at any point on the chart can be determined by measuring the chart length (or counting divisions) from the known time.***

4. The time of the reading is defined as the mean time of the interval chosen for analysis (see C "Selection of Interval").

C. Selection of interval to be analyzed within the fast-speed portion of the chart

The programming of the fast-speed portion of the wave record would logically be a direct function of the average period of waves during that portion. That is, the analysis is normally based on a given number of waves, and for equal numbers of waves measured per interval, one would select short and long fast-speed intervals for waves of shorter and longer periods, respectively. While this would be statistically consistent, it would require the impracticability of period forecasting and the inconvenience of variable programming, or the use of an excessive amount of chart paper. Hence the following plan is used, based on the analysis of a fixed time interval.

1. If the unit is programmed to run at fast speed for a longer time than 20 minutes, select the interval to include 20 minutes of the fast-speed portion and, if possible, select this interval such that its mid-point will approximately coincide with the mid-point of the fast-speed run.

---

* The Sangamo timer used for programming the frequency of fast runs and their duration may be used in a number of combinations.

** These periodic remarks should include time of observation, direction of waves, the stage of the tide, and descriptive remarks about the character of the water surface - such as calm, rough, white caps, etc.

*** Fast chart speed corresponds to 3 inches per minute, slow chart speed corresponds to 3 inches per hour.

2. In the event that this interval cannot be taken (due to the end of the chart or variation in cam action of the programmer), select as great an interval as may be possible, centering the interval so that at least one minute is allowed at the beginning of the interval in order for the chart speed to reach its full speed (particularly if the spring wound recorder is used).

A typical wave record has been analyzed and reproduced here to illustrate the analysis procedure*. Notice that the time of the beginning of the sampling interval is 0829 whereas the beginning time of the fast-speed run is at 0827. An interval of 20 minutes has been selected in this fast-speed portion, hence the end of the sampling interval is 0847.

The time of the interval being centered within this 20-minute interval is, therefore, 0839.

D. Determination of the characteristic period

1. Having defined the sampling interval, the next step is to select several groups of waves, within the interval, that contain a series of well-defined waves.

2. Measure the length of time from the beginning to the end of each of the series of well-defined waves and count the number of waves included in this series.

3. Divide the sum of the time-intervals of the groups of waves by the total number of waves counted in all such groups.

Thus $T_c = \frac{t}{n}$

where t = total time interval between the beginning and end of all well-defined series of waves.

n = total number of waves included in all of the series.

T_c = the characteristic wave period.

From the example, we see that there have been six such groups of waves selected and that the characteristic period of this interval is found to be

$$T_c = \frac{t}{n} = \frac{44 + 87 + 193 + 75 + 103 + 114}{3 + 6 + 13 + 5 + 7 + 8} = \frac{616}{42} = \underline{14.7 \text{ sec}}$$

E. Determination of the number of significant waves to be measured

1. Divide the interval by the characteristic wave period to determine the number of waves within the interval.

For example:

$$\frac{\text{Interval (in seconds)}}{\text{Period (seconds per wave)}} = N \text{ number of waves}$$

---

* This was not from one of the Guam recorders.

$$\frac{20 \times 60}{14.7} = \frac{1200}{14.7} = 82 \text{ waves}$$

2. Measure the highest N/3 waves ($N/3 = 82/3 \approx 27$)*

   (a) Scan the record selecting the highest waves observed until N/3 waves are selected.

   (b) Measure the height of the waves in divisions and record.

As may be seen in the sample analysis Data Sheet, the values of the wave heights have been recorded, the remaining part of the analysis being to arrive at the significant wave heights from these data.

F. Determination of significant wave heights

1. Determine the average of the highest N/3 waves as recorded (in this case 27 waves). Since the waves are measured in terms of the recorder chart divisions, the designation of this average is $R_1/3$. From the example, $R_1/3 = 15.9$**.

2. Record the maximum wave height encountered R_{max}, in this case 19.5 divisions.

G. Evaluation of wave heights from chart-divisions to wave height in feet-of-water

1. The following equation is used to obtain the surface wave height:

$$H = \frac{C}{K} R \qquad (1)$$

where H = wave height at surface, in feet.

C = calibration factor of the instrument in $\frac{\text{feet of water pressure}}{\text{chart divisions}}$

K = pressure response factor based upon depth of the instrument, depth of the water and length (or period) of wave being recorded

R = reading (in divisions) taken from chart as shown above.

2. Since the characteristic wave height and the maximum wave experience are the only two surface wave heights required in compiling the statistical information, only the values from the preceeding determination need be used as the value of "R" in the above equation (1).

---

* In the example given, the highest 30 waves have been selected for measurement, and after measurement, the three lowest of this group have been omitted from the average. Normally the analyst need select only 1/3 of the waves for measurement.

** Omitting 12, 12.5, 12.5 (three lowest values of the 30 selected for measurement)

Example:

$$H_{1/3} = \frac{R_{1/3}}{K} C$$

$$H_{1/3} = \frac{15.9}{0.822} \ 0.0755 = \underline{1.46 \text{ feet}}$$

$$H_{max} = \frac{19.5}{0.822} \ 0.0755 = \underline{1.79 \text{ feet}}$$

3. The value of C, 0.0755, was determined by laboratory test.

4. The values of K for various conditions of depth, period, etc. may be readily computed or obtained from prepared tables(6).

H. Recording the statistical information

The purpose of analyzing wave data is to finally compile statistics that give a time history of the characteristics of surface waves. This information may be tabulated on a form as shown below and eventually may be graphed to a time scale.

CHARACTER OF THE SEA TABLE

AT________________ FROM__________ TO__________

DAY	HOUR	T	$H_{1/3}$	H_{max}	REMARKS

SAMPLE ANALYSIS--DATA SHEET

POINT SUR, CALIFORNIA

ROLL NUMBER	273		
DATE	May 11, 1950		
TIME OF READING	0839		
PERIOD	13.6 sec.		
N/3	27		
WAVE NO.	WAVE HEIGHT - IN DIVISIONS		
1	14		
2	13.5		
3	13		
4	12.5*		
5	15		
6	17.5		
7	16		
8	17		
9	18		
10	19.5		
11	18		
12	14.5		
13	18		
14	15.5		
15	12.5*		
16	12*		
17	17		
18	16.5		
19	18		
20	18.5		
21	13		
22	13		
23	17		
24	17		
25	16		
26	16.5		
27	14		
28	12.5		
29	15		
30	15		
R_{max}	19.5		
$R_{1/3}$	15.9		
K	0.822		
$H_{1/3}$	1.46 Ft.		
H_{max}	1.79 Ft.		

K, the ratio of the subsurface pressure to the surface wave height, was determined for a depth of water of 65 feet and for an average period of 14.7 seconds.

* These values were not used (see footnote ** page AI-4)

APPENDIX II

WAVE RECORDS FOR GUAM.

One of the major by-products of the study of microseisms and waves at Guam was the obtaining of wave records to help develop a picture of the "wave climate". These records are presented herein. They supplement those obtained on a previous contract, which are presented in the report:

> Summary report on wave measurements at Apra Harbor, Guam, M.I. by A.J. Chinn and E.W. Winkler, Technical Report: Series 26, Issue 3, IER, University of California, Berkeley, Calif. August, 1950.

Ocean Wave Summary

for July 1952

Guam, Marianas Islands

Day	time	Orote Station			
		T	$H_{1/3}$	$H_{1/10}$	H_{max}
14	2400	10.6	1.6	2.3	3.0
15	0600	11.4	2.6	3.0	3.6
15	1200	10.2	2.3	2.6	3.3
15	2400	9.1	2.1	3.0	4.2
16	1200	9.2	2.0	2.4	2.7
16	2400	9.3	1.9	2.5	3.2
17	1200	8.5	1.3	1.7	2.2
17	2400	8.8	1.4	1.9	2.5
18	1200	-	-	-	-
18	2400	8.5	1.0	1.3	1.8
19	1200	8.4	1.3	1.7	2.4
19	2400	8.8	1.2	1.6	2.0
20	1200	10.4	.7	1.1	1.3
20	2400	9.5	1.3	1.7	2.2
21	1200	12.1	1.3	1.8	2.1
21	2400	11.0	1.3	1.7	2.0
22	1200	10.7	1.3	1.6	1.9
22	2400	10.3	1.2	1.6	2.0
23	1200	Less than one foot			
23	2400	10.4	1.0	1.2	1.4
24	1200	Under one foot			
24	2400	Less than one foot			
25	1200	Less than one foot			
25	2400	Less than one foot			
26	1200	Less than one foot			
26	2400	Instrument out			
27	1200	Less than one foot			
27	2400	8.2	0.6	1.3	1.4
28	1200	Instrument out of ink			
28	1800	8.5	1.4	1.9	2.4
28	2400	Instrument out			
29	1200	8.8	1.9	2.4	2.7
29	2400	9.6	2.4	2.8	3.4
30	1200	9.7	1.4	1.9	3.2
30	2400	9.0	1.8	2.1	2.6
31	1200	8.6	0.8	1.7	2.2
31	2400	About 1 foot			

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Ocean Wave Summary
for August 1952
Guam, Marianas Islands

Day	time	Orote Station				Tarague Station				Ylig Station			
		T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
1	1200	About 1 foot											
1	2400	Less than 1 foot											
2	1200	About 1 foot											
2	2400	6.4	2.2	2.7	3.6								
3	1200	5.9	2.8	3.5	5.0								
3	2400	6.9	3.7	4.9	7.2								
4	1200	7.0	4.4	4.9	6.2								
4	2300	7.8	5.5	7.2	8.5								
5	1200	7.9	5.8	7.6	9.9								
5	2400	7.2	5.4	5.7	8.3								
6	0600	8.8	4.6	5.7	6.6								
6	1200	8.4	4.7	5.6	8.1								
6	1800	8.4	4.3	5.6	7.0								
6	2400	7.9	3.9	6.2	7.6								
7	1200	9.5	6.2	6.5	10.4								
7	2400	10.1	6.2	7.5	9.5								
8	0600	9.3	4.2	5.0	6.4								
8	1200	8.5	4.5	5.4	6.0								
8	2400	9.3	2.9	3.5	4.9								
9	1200	8.7	2.6	3.3	4.4								
9	2400	Less than 1 foot											
10	1200	Less than 1 foot				7.0	2.0	estimated					
10	2400Z	Less than 1 foot				7.0	1.5	"					
11	1200Z	"	"	"		7.0	1.5	"					
11	2400Z	"	"	"		7.0	1.5	"					
12	1200Z	Less than 1 foot				7.0	1.5	estimated					
12	2400Z	"	"	"		6.0	1.0	"					
13	1200Z	"	"	"		6.0	1.0	"					
13	2400Z	"	"	"		7.0	1.5	"					
14	1200Z	11.4	1.4	1.8	2.3	7.0	2.0	estimated					
14	2400Z	9.3	1.4	1.7	2.9	7.0	1.5	"		7.0	2.5	estimated	
15	2400Z	9.2	1.8	2.3	2.7	7.0	2.5	"		7.0	2.0	"	
15	2400Z	less than 1 foot				7.0	2.0	"		7.0	2.0	"	
16	1200Z	less than 1 foot				7.0	1.5	estimated		7.0	1.5	estimated	
16	2400Z	"		"		7.0	1.5	"		7.0	1.5	"	
17	1200Z	8.9	1.5	1.7	2.3	7.0	1.5	"		7.0	1.5	"	
17	2400Z	8.8	1.5	1.8	2.2	Record obtained but not analyzed				9.8	1.6	2.0	2.8
18	1200Z	9.2	1.3	1.6	1.9	Record obtained but not				8.2	1.6	1.9	2.5
18	2400Z	10.8	1.3	1.8	2.9	analyzed				9.2	1.2	1.6	2.0
19	1200Z	10.4	1.6	1.9	2.3	"				10.4	1.1	1.2	1.6
19	1800Z	9.9	1.5	1.9	2.3	"				Not analyzed			
19	2400Z	10.8	1.7	2.2	2.7	"				"			

AII-3

Ocean Wave Summary, continued

August 20 - September 3, 1952

Guam, Marianas Islands

AUGUST 1952		Orote Station				Tarague Station				Ylig Station			
Day	time	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
20	0600	11.0	1.9	2.3	2.7	Record obtained but				Less than 1 foot			
20	1200	10.8	2.0	2.5	2.8	not analyzed				-	-	-	-
20	2400	10.2	1.4	1.7	2.3	"				About 1 foot			
21	1200	10.0	1.6	2.0	3.0	"				8.1	1.2	1.8	2.6
21	2400	One foot or less				"				8.4	1.8	2.2	2.6
22	1200	less than 1 foot				Waves about 2 to 3 ft.				8.8	1.7	2.3	2.6
22	2400	about 1 foot				in height with 6-8				8.9	1.6	1.9	2.2
23	1200	less than 1 foot				sec periods.				8.0	1.7	1.6	2.8
23	2400	less than 1 foot.								one foot and less			
24	1200	less than 1 foot				"				one foot and less			
24	2400	less than 1 foot				"				1 to 2 feet.			
25	1200	less than 1 foot				"				about 2 feet			
25	2400	about 1 foot				"				5.6	3.7	4.7	5.5
26	1200	about 1 foot				5.4	3.2	2.9	3.5	6.3	2.9	3.7	4.8
26	2400	about 1 foot				5.6	3.3	4.0	5.3	6.3	3.2	4.1	5.2
27	1200	about 1 foot				6.6	2.3	3.0	3.5	6.8	2.9	3.5	4.1
27	2400	about 1 foot				5.8	2.5	2.9	4.3	6.3	3.5	4.9	6.6
28	1200	about 1 foot				6.6	2.0	2.5	3.0	6.7	3.6	4.7	6.6
28	2400	about 1 foot				6.9	1.7	2.3	3.2	6.8	3.2	4.1	5.1
29	1200	about 1 foot				8.2	1.3	1.5	1.8	8.5	2.0	2.8	3.5
29	2400	7.1	1.3	1.6	2.0	8.2	1.3	1.6	2.2	7.7	2.4	2.9	3.2
30	1200	8.1	1.6	2.0	2.4	5.7	1.8	2.3	3.3	8.2	2.0	2.4	3.0
30	2400	8.0	1.9	2.0	3.9	5.8	2.8	3.5	4.9	6.9	3.0	3.7	4.8
31	1200	10.6	2.7	3.3	4.7	6.0	3.2	4.0	5.1	7.6	3.6	4.3	5.0
31	1800	10.5	2.3	2.8	3.3	7.1	3.5	5.2	5.8	7.6	3.4	4.1	5.5
31	2400	10.1	2.2	3.0	4.3	7.3	3.3	3.9	5.4	7.3	4.7	5.9	7.7
SEPTEMBER 1952													
1	0600	10.2	2.0	2.4	2.7	7.6	3.2	3.8	4.4	7.4	4.1	5.5	6.4
1	1200	10.2	2.9	3.7	5.0	7.7	3.1	3.7	4.6	8.7	3.9	4.8	5.5
1	1800	10.0	2.5	3.4	3.7	7.7	3.0	3.8	5.7	8.4	3.4	4.2	4.6
2	0000	8.6	2.5	3.0	3.8	7.2	3.2	4.1	6.8	8.0	4.0	4.6	7.5
2	0600	8.9	2.3	2.9	3.8	6.8	3.5	4.1	6.2	7.5	3.6	4.4	5.4
2	1200	9.0	2.4	3.0	3.8	6.7	2.9	3.3	5.5	7.7	2.8	3.6	5.5
2	1800	8.2	1.7	2.1	2.4	8.6	2.4	2.9	3.4	8.3	2.6	3.3	3.9
3	0000	8.3	1.9	2.1	2.6	8.4	2.6	3.4	4.0	9.2	2.8	3.8	5.5
3	0600	8.5	1.6	2.2	2.7	8.6	2.4	2.9	3.5	8.8	3.0	3.8	4.9
3	1200	7.5	2.0	2.4	3.3	9.3	2.2	2.7	3.2	9.1	2.7	3.2	3.9
3	1800	8.2	1.6	2.2	2.8	8.3	2.4	2.9	4.1	8.7	2.8	3.3	4.4

AII-4

Ocean Wave Summary, cont'd
Sept. 4 - 13 1952
Guam, Marianas Islands

SEPTEMBER 1952		Orote Station				Tarague Station				Ylig Station			
Day	time	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
4	0000	7.6	1.7	2.2	2.8	9.4	2.1	2.5	3.1	8.5	2.4	3.0	4.0
4	0600	8.1	1.3	1.6	2.0	about 2 feet				8.8	2.2	2.7	3.8
4	1200	about 1 foot				9.1	1.9	3.2	3.8	9.1	1.8	2.4	3.2
4	1800	9.3	1.2	1.5	1.9	8.1	1.9	2.2	2.8	8.4	2.0	2.6	3.9
5	0000	7.7	1.8	2.3	3.3	7.5	2.1	2.8	3.1	8.7	1.7	2.1	2.6
5	0600	7.6	1.3	1.7	2.4	line trouble				7.0	2.4	3.1	3.8
5	1200	7.3	1.5	1.9	2.6	7.6	2.9	3.0	3.6	7.7	2.1	2.8	3.7
5	1800	8.3	1.7	2.1	2.6	6.5	2.3	2.8	3.4	6.9	2.2	3.0	4.2
6	0000	8.5	1.6	1.9	2.3	8.5	1.9	2.4	3.0	6.6	2.1	2.9	4.3
6	0600	6.8	1.7	2.1	2.7	8.3	2.2	2.7	3.2	7.9	2.0	2.5	3.2
6	1200	7.2	1.1	2.4	3.2	7.4	2.0	2.5	2.8	8.4	1.6	2.0	2.8
6	1800	8.3	1.8	2.2	3.0	8.5	2.0	2.3	2.8	6.6	2.1	3.0	4.5
7	0000	8.0	1.9	2.6	3.5	8.6	1.9	2.4	3.3	9.3	1.8	2.4	2.7
7	0600	8.0	2.3	2.9	4.0	8.1	1.9	2.2	2.8	8.3	2.2	2.9	3.9
7	1200	7.7	2.0	2.4	2.9	9.2	1.9	2.3	2.8	8.7	1.9	2.4	3.2
7	1800	7.4	2.0	2.6	3.5	9.8	1.9	2.4	3.1	8.0	2.2	2.8	3.2
8	0000	8.2	2.7	3.2	3.6	9.2	1.7	1.9	2.9	9.0	1.9	2.3	2.7
8	0600	8.1	2.4	3.0	4.1	9.7	1.6	2.0	2.3	Instrument trouble			
8	1200	7.3	2.8	3.4	5.0	9.5	1.3	1.6	2.4	9.3	1.3	1.2	1.9
8	1800	7.5	3.0	3.8	4.9	9.6	1.5	1.9	2.2	9.3	1.6	2.1	3.1
9	0000	8.0	3.1	4.1	5.4	9.1	1.7	2.0	2.2	9.4	1.3	1.7	2.4
9	0600	8.1	2.8	3.3	4.0	Instrument trouble				8.9	1.3	1.6	2.0
9	1300	8.0	2.3	2.9	3.6	9.6	1.5	2.0	2.7	8.9	1.6	1.8	2.2
9	1800	8.2	1.8	2.2	2.6	1 to 2 feet				8.6	1.4	1.8	2.7
10	0000	8.1	1.9	2.5	3.5	6.8	1.8	2.0	2.5	8.9	1.4	1.7	2.1
10	0600	8.0	1.5	2.1	2.5	About 1 foot				1 to 2 feet			
10	1200	8.2	2.0	2.3	2.8	About 1 foot				about 1 foot			
10	1800	8.5	1.6	2.1	2.7	1 to 2 feet				1 to 2 feet			
11	0000	8.0	1.3	1.6	1.9	About 2 feet				1 to 2 feet			
11	0600	8.3	1.3	1.6	1.9	1 to 2 feet				1 foot or less			
11	1200	7.4	1.2	1.6	2.0	4.9	2.5	3.1	4.7	5.0	2.8	3.7	2.0
11	1800	7.7	1.3	1.7	2.2	5.6	2.4	2.9	3.9	5.4	3.3	4.1	5.5
12	0000	About 1 foot				5.8	2.6	3.3	4.9	6.5	3.1	4.0	5.3
12	0600	About 1 foot				6.0	3.0	3.5	4.4	6.5	3.3	4.2	5.6
12	1200	7.0	1.6	1.9	2.5	5.9	1.6	2.8	3.5	6.7	2.5	3.3	4.3
12	1800	1 to 2 feet.				5.9	2.5	3/2	4.1	6.2	3.1	3.9	4.9
13	0000	1 to 2 feet				5.8	3.1	3.8	4.9	6.0	3.0	3.7	5.5
13	0600	1 to 2 feet				5.8	2.9	3.6	4.7	6.0	3.1	4.0	5.7
13	1200	less than 1 foot				5.9	2.6	3.3	4.4	line trouble			
13	1800	less than 1 foot				6.1	2.2	2.8	3.5	6.1	2.5	3.3	4.3

Ocean Wave Summary, cont'd.
Sept. 14 - 23, 1952
Guam, Marianas Islands

SEPTEMBER 1952		Orote Station				Tarague Station				Ylig Station			
Day	time	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
14	0000	About 1 foot				5.8	2.2	2.7	3.7	6.0	2.5	3.0	3.6
14	0600	Less than 1 foot				6.0	1.6	2.2	2.7	6.2	2.0	2.5	3.6
14	1200	About 1 foot				7.7	1.6	1.9	2.4	5.8	2.1	2.6	3.6
14	1800	Less than 1 foot				1 to 2 feet				1 to 2 feet			
15	0000	Less than 1 foot				5.2	2.2	2.9	4.1	6.9	2.5	3.1	3.7
15	0600	Less than 1 foot				6.0	1.6	2.2	2.7	6.2	2.0	2.5	3.6
15	1200	Less than 1 foot				7.7	1.6	1.9	2.4	5.8	2.1	2.6	3.6
15	1800	Less than 1 foot				1 to 2 feet				2 to 3 feet			
16	0000	Less than 1 foot				5.7	2.3	2.8	3.6	6.6	2.8	3.4	4.2
16	0600	Less than 1 foot				1 to 2 feet				2 to 3 feet			
16	1200	Less than 1 foot				7.2	1.7	2.2	3.3	8.4	2.1	2.8	3.4
16	1800	Less than 1 foot				2 to 3 feet				2 to 3 feet			
17	0000	Less than 1 foot				2 to 3 feet				10.7	2.6	3.2	4.0
17	0600	Less than 1 foot				10.5	1.8	2.1	2.5	10.0	2.4	3.1	3.6
17	1200	Less than 1 foot				10.3	2.2	2.7	3.0	11.1	2.7	3.6	4.5
17	1800	Less than 1 foot				10.3	2.2	2.7	3.0	11.1	2.7	3.6	4.5
18	0000	About 1 foot				12.4	2.1	2.6	2.9	11.8	3.0	3.8	5.3
18	0600	11.9	0.9	1.2	1.5	14.5	2.8	3.5	4.1	13.5	3.7	4.3	5.1
18	1200	About 1 foot				10.5	2.8	3.5	4.2	12.3	3.5	4.5	6.8
18	1800	14.4	1.4	1.6	1.9	11.9	2.9	3.8	5.4	10.8	2.5	3.3	3.8
19	0000	10.9	1.2	1.2	1.5	15.6	3.6	4.4	5.5	11.3	3.3	4.3	5.0
19	0600	14.0	1.2	1.5	1.8	13.0	2.5	2.9	3.3	13.5	2.5	3.0	3.4
19	1200	13.3	1.1	1.3	1.4	12.3	2.7	3.2	3.7	9.7	2.0	2.5	2.9
19	1800	8.7	1.6	2.0	2.3	11.1	2.7	3.3	4.0	10.7	1.8	2.2	2.7
20	0000	11.8	1.4	1.7	1.9	10.7	2.2	2.8	3.4	10.4	1.8	2.3	2.5
20	0600	10.0	1.5	1.8	2.0	11.6	2.4	3.1	4.0	8.7	1.7	2.2	3.6
20	1200	8.7	1.7	2.1	2.6	10.6	2.0	2.4	3.3	9.9	1.3	1.7	2.3
20	1800	11.0	1.9	2.4	3.0	10.4	1.9	2.4	2.9	1 to 2 feet			
21	0000	10.8	1.7	2.2	2.7	10.5	2.0	2.5	3.1	1 foot or less			
21	0600	11.6	1.9	2.3	3.0	11.0	2.2	2.7	3.3	9.3	1.5	1.9	2.3
21	1200	11.6	2.1	2.6	2.8	11.3	2.0	2.3	2.5	9.4	1.2	1.5	1.6
21	1800	11.3	2.0	2.4	2.6	10.3	2.5	3.1	3.9	8.8	1.6	2.0	2.8
22	0000	10.9	1.5	1.8	2.1	9.6	2.7	3.3	4.0	10.0	1.5	1.9	2.4
22	0600	9.6	1.8	2.2	3.3	5.8	2.3	3.1	4.0	6.2	2.4	3.1	4.5
22	1200	10.0	1.6	1.9	2.1	9.2	2.1	2.5	2.9	6.6	2.2	2.8	3.2
22	1800	9.4	1.8	2.2	2.6	6.0	2.7	3.3	4.0	6.3	2.7	3.4	5.0
23	0000	10.2	1.4	1.7	2.1	6.4	2.3	2.7	4.0	6.2	2.5	3.1	4.0
23	0600	9.9	1.4	1.7	2.0	6.8	2.1	2.5	3.3	7.3	2.0	2.5	3.5
23	1200	9.6	1.2	1.5	2.0	7.3	1.9	2.4	3.4	8.7	2.0	2.5	3.2
23	1800	-	-	-	-	-	-	-	-	-	-	-	-

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Ocean Wave Summary, cont'd
Sept. 23 - 7 October 1952
Guam, Marianas Islands

SEPTEMBER 1952		Orote Station				Tarague Station				Ylig Station			
Day	time	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
24	0000	9.0	1.2	1.3	1.5	8.6	1.8	2.1	2.6	8.8	1.8	2.2	2.6
24	0600	-	-	-	-	-	-	-	-	-	-	-	-
24	1200	About 1 foot				6.6	1.8	2.2	3.2	10.4	1.5	1.9	2.4
24	1800	Less than 1 foot				1 to 2 feet				1 to 2 feet			
25	0000	Less than 1 foot				1 to 2 feet				10.5	1.6	2.0	2.6
25	0600	-	-	-	-	-	-	-	-	-	-	-	-
25	1200	Less than 1 foot				6.4	1.9	2.3	2.7	9.3	1.4	1.8	2.2
25	1800	-	-	-	-	-	-	-	-	-	-	-	-
26	0000	About 1 foot				6.9	2.3	2.8	3.6	7.3	2.2	2.7	3.6
26	0600	-	-	-	-	-	-	-	-	-	-	-	-
26	1200	About 1 foot				6.5	2.3	2.8	3.8	7.2	1.9	2.5	3.9
26	1800	-	-	-	-	-	-	-	-	-	-	-	-
27	0000	9.8	1.9	2.1	2.5	8.3	3.4	4.0	6.0	8.2	2.8	3.6	4.5
27	0600	8.7	1.3	1.8	2.4	8.5	2.9	3.7	4.1	9.1	3.8	4.9	6.6
27	1200	8.5	1.3	1.7	2.2	8.6	2.6	3.3	4.8	9.3	2.5	3.1	4.1
27	1800	-	-	-	-	-	-	-	-	-	-	-	-
28	0000	9.9	1.6	2.0	2.5	8.8	2.9	3.5	4.2	9.0	3.7	4.7	5.7
28	0600	-	-	-	-	-	-	-	-	-	-	-	-
28	1200	10.6	1.1	1.4	1.7	8.3	2.6	3.3	3.9	8.5	3.4	4.1	5.0
28	1800	-	-	-	-	-	-	-	-	-	-	-	-
29	0000	6.6	2.2	2.7	3.4	7.9	1.9	2.4	2.8	7.9	2.8	3.5	3.8
29	0600	7.1	3.2	3.9	4.6	9.0	1.7	2.1	2.4	8.1	2.8	3.3	4.8
29	1200	7.9	2.9	3.6	5.0	8.7	1.6	1.9	2.3	8.4	2.4	3.0	4.1
30	0000	8.0	3.9	4.9	6.7	9.6	1.5	1.8	2.2	8.7	2.2	2.8	4.0
30	1200	8.3	4.5	5.6	7.6	10.0	1.4	1.8	2.5	8.7	2.4	2.6	3.4
OCTOBER 1952													
1	0000	8.0	3.8	4.6	5.7	9.4	1.8	2.2	2.7	8.4	2.2	2.8	3.6
1	0600	8.2	2.7	3.3	4.2	8.6	1.6	2.1	2.8	8.5	2.1	2.8	3.5
1	1200	7.2	3.0	3.7	4.8	8.8	2.1	2.7	3.5	8.5	2.4	3.1	4.2
2	0000	8.0	3.1	3.9	5.1	8.8	2.5	3.1	4.0	9.2	3.0	3.8	4.7
2	1200	9.4	4.3	5.4	8.0	9.4	2.4	3.1	3.3	8.9	2.7	3.3	4.3
3	0000	10.8	4.8	5.9	7.2	13.0	3.1	3.9	5.2	8.5	1.9	2.5	3.8
3	1200	12.8	5.0	6.3	7.0	12.4	3.6	4.5	5.1	7.8	1.8	2.4	3.0
4	0000	12.8	5.5	6.5	7.8	12.2	3.1	3.7	5.4	8.4	1.7	2.2	2.8
4	1200	12.0	3.9	4.7	5.8	12.6	2.8	3.7	4.8	8.5	1.4	2.6	4.0
5	0000	11.9	2.4	2.9	3.4	11.9	2.8	3.6	5.2	8.8	2.1	2.7	3.2
5	1200	11.1	1.8	2.7	4.1	2 to 3 feet				1 to 2 feet			
6	0000	12.6	2.4	3.1	4.0	9.6	1.7	2.1	2.8	9.3	1.6	2.0	2.6
6	1200	10.9	2.5	3.1	3.7	12.4	2.4	2.8	3.2	About 1 foot			
7	0000	10.5	2.1	2.6	3.1	13.3	2.4	2.8	3.6	8.7	1.5	1.7	2.8
7	1200	12.8	3.1	4.3	5.9	12.4	2.2	2.6	2.1	8.9	1.5	1.9	2.5

Ocean Wave Summary
October 8 - 23, 1952
Guam, Marianas Islands

OCTOBER 1952		Orote Station				Tarague Station				Ylig Station			
Day	Time	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
8	0000	12.4	2.6	3.1	3.8	12.3	2.2	2.7	3.5	8.4	1.4	1.8	2.5
8	1200	11.5	2.4	2.9	3.4	12.2	2.5	2.9	3.0	6.5	2.5	3.3	4.1
9	0000	12.4	1.9	2.3	2.7	2 to 3 feet				1 to 2 feet			
9	1200	11.9	2.2	2.7	3.0	11.8	2.3	2.8	3.3	1 to 2 feet			
10	0000	10.1	2.0	2.4	3.0	7.4	2.3	2.9	4.2	9.2	2.4	2.9	3.4
10	1200	10.5	2.0	2.5	2.8	11.0	2.6	3.1	4.2	8.4	2.4	2.9	3.4
11	0000	10.0	1.8	2.2	3.2	8.9	2.3	2.9	3.8	8.8	2.6	3.3	4.1
11	1200	9.8	1.6	2.0	2.3	8.9	2.3	2.9	3.3	8.1	2.7	3.5	4.8
12	0000	9.7	1.7	1.9	2.2	8.5	2.3	3.0	3.4	8.5	2.6	3.5	5.7
12	1200	About 1 foot				8.0	3.0	3.8	1.6	8.4	3.0	3.8	4.3
13	0000	About 1 foot				6.8	3.5	4.3	5.9	7.5	3.0	3.6	4.4
13	1200	About 1 foot				7.0	4.0	5.1	7.9	7.6	4.1	5.0	6.1
14	0000	About 1 foot				7.4	4.4	5.4	7.2	7.7	4.6	5.3	7.2
14	1200	Less than 1 foot				7.7	3.4	4.0	4.7	8.1	4.3	5.2	6.5
15	0000	9.9	1.1	1.7	2.0	7.4	2.8	3.3	4.3	7.5	3.6	4.7	6.2
15	1200	9.8	1.4	1.9	2.9	8.0	2.9	3.5	4.6	9.8	3.0	3.9	5.6
16	0000	9.3	1.4	1.8	1.9	8.4	2.7	3.4	4.2	8.3	3.2	4.0	5.1
16	1200	About 1 foot				8.3	2.4	3.0	3.7	8.5	2.6	3.2	4.3
17	0600	9.7	1.1	1.6	1.9	10.6	4.0	5.0	5.6	10.9	3.6	4.2	5.6
17	1200	11.8	1.7	2.0	2.4	11.3	3.9	4.6	5.3	11.6	4.7	5.6	7.4
17	1800	10.1	1.4	1.7	2.4	11.9	3.9	4.7	5.7	12.0	4.0	4.7	5.4
18	0000	10.9	1.6	1.9	2.3	11.0	3.7	4.4	5.4	11.9	4.4	5.5	6.1
18	1200	9.4	1.5	1.9	2.6	11.5	4.5	5.5	6.4	11.2	4.3	5.3	6.9
19	0000	9.9	1.7	2.1	2.7	9.2	3.7	4.4	5.5	10.9	4.9	6.1	6.6
19	0600	7.8	1.8	2.2	2.6	7.2	4.9	6.1	8.3	9.5	5.1	7.0	9.1
19	1200	9.0	1.7	2.0	2.4	9.1	3.1	4.0	5.5	9.8	4.3	5.1	5.9
19	1800	9.3	2.1	2.6	3.1	9.3	3.4	4.3	5.3	10.4	3.3	4.0	4.9
20	0000	10.1	2.1	2.7	3.2	10.8	3.5	4.2	5.0	10.5	3.3	4.0	4.9
20	1200	10.2	2.7	3.2	3.6	9.7	2.9	3.4	4.5	10.3	3.2	4.0	4.5
21	0000	11.3	3.2	3.7	3.9	9.6	4.2	4.9	7.0	10.1	4.6	5.7	7.4
21	0600	10.6	3.0	3.7	4.1	9.7	4.3	5.4	6.0	10.1	4.6	5.7	7.7
21	1200	10.8	3.1	3.7	4.9	10.2	4.1	5.0	6.6	10.9	5.5	7.5	11.6
21	1800	12.7	3.5	4.3	5.8	11.2	4.8	5.2	9.8	11.5	5.5	6.7	8.5
22	0000	11.7	5.3	6.8	8.2	11.1	4.4	5.3	6.8	11.9	5.9	7.0	7.8
22	0600	11.7	3.8	4.5	5.6	12.9	4.4	6.2	7.3	12.2	5.9	7.4	10.0
22	1200	12.1	4.7	5.8	8.1	12.5	4.6	5.8	7.3	11.6	5.2	6.4	7.4
23	0000	11.1	2.8	3.5	4.3	11.8	4.1	5.1	7.1	11.8	5.4	7.1	9.4
23	0600	11.6	3.2	3.9	4.5	11.2	4.1	5.2	6.1	11.3	4.9	5.1	6.7
23	1200	10.8	2.4	2.9	3.7	10.2	3.5	4.1	4.8	9.8	5.1	6.1	8.1
23	1800	10.3	2.2	2.6	3.1	9.4	3.4	4.0	4.8	10.4	6.2	7.1	9.4

Ocean Wave Summary
October 24 - November 12, 1952
Guam, Marianas Islands

OCTOBER 1952		Orote Station				Tarague Station				Ylig Station			
Day	Time	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
24	0000	10.1	2.1	2.4	2.7	10.0	3.5	4.6	5.7	8.7	5.3	6.6	9.2
24	0600	10.6	2.5	3.0	4.0	10.5	3.5	4.5	6.0	9.9	6.2	7.6	9.5
24	1200	10.0	2.4	3.0	4.0	9.4	3.1	3.7	5.5	8.9	5.6	6.7	8.1
24	1800	10.2	3.0	4.0	5.1	9.2	3.5	4.3	5.5	9.5	4.6	5.8	7.3
25	0000	9.9	3.3	4.0	5.5	9.2	3.1	4.0	5.1	9.2	4.5	5.4	7.2
25	1200	10.3	2.3	2.8	4.5	9.6	2.4	2.7	3.0	8.0	3.1	3.9	4.6
26	0000	9.8	2.6	3.4	5.3	9.1	2.6	3.1	3.7	9.3	3.2	4.0	5.3
26	1200	9.6	2.6	3.4	4.0	9.8	2.6	3.4	4.3	Instrument trouble			
27	0000	9.6	2.4	2.9	3.5	9.8	3.2	4.0	4.8	9.8	3.1	3.8	5.1
27	1200	8.4	2.4	3.1	4.4	9.5	2.9	3.8	5.2	9.9	3.2	3.9	4.5
28	0000	9.7	2.6	3.4	4.9	9.6	3.9	4.9	6.6	10.3	5.0	6.2	7.8
28	1200	11.5	2.8	3.5	4.9	9.9	4.0	5.1	8.0	9.9	6.0	7.8	9.1
29	0000	10.6	2.7	3.1	3.8	8.9	4.9	6.1	8.7	9.9	6.0	7.2	9.6
29	1200	9.9	3.2	4.0	4.8	9.6	4.5	5.6	6.7	9.4	6.5	7.9	9.6
30	0000	9.8	2.2	2.8	3.4	9.5	4.5	5.4	6.2	9.4	4.8	5.7	9.3
30	1300	10.2	1.8	2.2	2.7	9.9	5.3	6.7	8.6	9.7	6.5	8.2	9.0
31	0000	7.0	2.2	2.5	3.4	9.2	3.3	4.0	5.2	9.1	5.4	6.9	7.7
31	1200	7.2	2.2	2.7	3.2	9.3	2.5	3.1	4.6	9.3	4.2	5.4	7.5
NOVEMBER 1952.													
1	0000Z	About 1 foot				10.0	2.0	2.4	2.7	10.2	3.6	4.5	5.7
1	1200Z	10.6	1.9	2.2	2.4	10.7	2.1	2.6	3.1	9.9	2.9	3.5	3.8
2	0000Z	8.6	1.6	2.0	2.7	9.6	1.6	2.1	2.7	10.0	2.3	2.9	3.4
2	1200Z	8.0	2.0	2.4	2.9	1 to 2 feet				9.5	2.1	2.7	3.3
3	0000	10.9	1.7	2.1	2.6	About 1 foot				9.4	2.0	2.6	3.3
3	1200	11.5	1.9	2.4	3.4	About 1 foot				8.3	1.5	1.9	2.7
4	0000	10.0	2.4	2.9	3.7	7.7	2.5	3.1	3.8	9.1	2.7	3.2	3.9
4	1200	10.9	2.3	2.9	3.3	8.5	2.5	3.1	4.5	8.2	3.8	4.8	5.8
5	0000	10.8	2.6	3.6	4.8	9.5	2.3	2.9	3.4	8.0	3.1	3.8	4.6
5	1200	11.2	2.5	3.0	3.6	About 2 feet.				8.6	2.9	3.5	4.5
6	0000	12.4	2.6	3.2	3.7	8.6	2.6	2.9	3.8	8.0	3.0	3.2	4.6
6	1200	11.7	2.2	2.7	3.2	8.8	2.5	3.1	3.8	7.5	3.7	4.9	6.0
7	0000	11.7	2.1	2.6	3.0	8.5	2.7	3.4	4.7	8.0	3.4	4.1	5.7
8	0000	12.6	3.1	3.8	5.1	Two distinct trains 7 & 14 sec. 3-4 ft. Max. 7 ft.				6.7	4.6	5.6	7.9
9	0000	11.8	2.7	3.4	4.5	7.3	3.1	4.0	5.4	8.3	4.6	5.8	6.9
10	0000	11.9	1.9	---	2.6	7.5	3.1	---	5.6	8.0	4.2	---	5.8
11	0000	10.5	1.6	2.1	2.4	About 2 feet				8.2	2.9	3.6	4.5
12	0000	About 1 foot or less				1 to 2 feet				1 to 2 feet			

Ocean Wave Summary
November 16- 29, 1952
Guam, Marianas Islands

NOVEMBER 1952		Orote Station				Taraguo Station				Ylig Station			
Day	Time	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}	T	$H_{1/3}$	$H_{1/10}$	H_{max}
16	0000	11.4	1.5	1.7	1.8	9.6	3.3	4.2	5.3	9.1	6.6	8.6	10.8
17	0000	10.4	2.1	2.5	2.8	9.2	2.3	2.8	3.4	8.9	3.3	4.1	4.8
18	0000	About 1 foot				7.4	2.2	2.9	4.3	7.7	3.7	4.7	6.0
21	0000	Less than 1 foot				9.0	4.5	5.9	7.4	10.0	9.2	10.7	12.9
21	0600	About 1 foot				9.3	5.6	6.5	8.5	10.3	8.9	10.3	14.5
21	1200	About 1 foot				9.8	5.0	5.8	9.3	10.4	8.2	9.9	14.2
21	1800	1 to 2 feet				8.9	6.9	8.5	9.5	8.4	8.6	10.7	13.6
23	0000	11.7	1.3	2.0	2.5	9.1	3.1	3.9	5.5	9.9	5.8	7.2	10.4
25	0000	9.7	1.2	1.8	2.0	8.8	2.5	2.9	3.5	9.8	5.1	6.4	7.5
29	0000	11.0	2.9	3.5	4.3	10.9	2.6	3.2	4.3	8.9	3.8	4.5	5.7

APPENDIX III.

OPERATION PROCEDURE FOR GUAM TELEMETERING SYSTEM

(These notes apply for only one channel, and should be repeated for each of the three.)

1. Calibration of the Telemetering system:

The following requires two operators, one at the field site, and one at the main office.

	office	field site
a)	Standby	Set pressure head switch to (1). Set operation switch to NORMAL. Adjust Mk IX bridge current to 32 milliamps.
b)	Switch recorder to high speed	Change pressure head switch to (2) position.
c)	With sensitivity switch in HIGH position, adjust the HIGH calibration knob (lower knob) so that the recorder pen rides on the outer line of the chart.	Standby.
d)	With the sensitivity switch in the LOW position, adjust the LOW calibration knob (upper knob) so that the recorder pen rides half way between the middle of the chart and the edge	Standby
e)	Change sensitivity switch to appropriate range.	Change pressure head switch to (1) position.
	Switch recorder to slow speed. Secure	Secure

2. Calibration of the Battery System at the Field Site: (no operator needed in the office.

a) Connect the battery

b) Change the operation switch to emergency and remove the clamp from the recorder starter mechanism. The red light should light and the recorder should start. If the red light does not light, press the test button for 30 seconds.

c) Change the pressure head switch to the (2) position

d) With the sensitivity switch in the HIGH position, adjust the HIGH sensitivity knob inside the Mark IX bridge so that the local recorder pen rides on the outside edge of the chart.

e) With the sensitivity switch in the LOW position, adjust the LOW sensitivity knob so that the pen rides half way between the center of the chart and the edge.

f) Return the operation switch to NORMAL, disconnect the battery, and shut off the chart drive. Replace the clamp on the recorder starter mechanism.

g) Return the pressure head switch to the (1) position.

3. Preparation for Emergency Operation:

a) Follow the instructions a) through e) above in the calibration of the battery system.

b) Quickly flip the operation switch up to NORMAL, and then back to EMERGENCY. The red light should not light.

c) Reset the chart drive and wind the spring motor. Do not replace the clamp on the starter mechanism.

d) Check the circuit by pushing the test bottom for 30 seconds. The red light should light and the chart drive should start.

e) Repeat step b) and c).

f) Check to see that the recorder has a full roll of paper and that the ink well is full and the pen is started.

4. Discontinuing Emergency Operation:

a) Reset the chart drive if it is tripped, and replace the starter mechanism clamp.

b) Change the operation switch to NORMAL

c) Disconnect the battery wires.

d) Calibrate the telemetering system.

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